US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL Technical Report EP-95/08
March 1995

Hazardous Waste Minimization Assessment: Fort Riley, KS

by
Andrew E. Isbell
William G. Newbould
Bernard A. Donahue

On November 8, 1984, the U.S. Congress signed into public law the Hazardous and Solid Waste Amendments (HSWA) act establishing a national policy on waste minimization. Regulations created to support the HSWA require hazardous waste generators to develop and follow a hazardous waste minimization program. Moreover, the Department of Defense has established a goal of 50 percent reduction in hazardous waste generation by 1992 (compared to 1985 generation data).

After studying hazardous waste generation and current methods of treatment, storage, and disposal, researchers conducted feasibility and economic analyses of hazardous waste minimization options and prepared a hazardous waste minimization (HAZMIN) plan for Fort Riley, KS.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1995	Final

4. TITLE AND SUBTITLE
Hazardous Waste Minimization Assessment: Fort Riley, KS

5. FUNDING NUMBERS
MIPR
DEHM910097,
dated 13 August 1991

6. AUTHOR(S)
Andrew E. Isbell, William G. Newbould, and Bernard A. Donahue

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
EP-95/08

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Directorate of Environment and Safety
ATTN: AFZN-ES-P
1970 Second Street
Fort Riley, KS 66442-6016

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

On November 8, 1984, the U.S. Congress signed into public law the Hazardous and Solid Waste Amendments (HSWA) act establishing a national policy on waste minimization. Regulations created to support the HSWA require hazardous waste generators to develop and follow a hazardous waste minimization program. Moreover, the Department of Defense has established a goal of 50 percent reduction in hazardous waste generation by 1992 (compared to 1985 generation data).

After studying hazardous waste generation and current methods of treatment, storage, and disposal, researchers conducted feasibility and economic analyses of hazardous waste minimization options and prepared a hazardous waste minimization (HAZMIN) plan for Fort Riley, KS.

14. SUBJECT TERMS
Hazardous Waste Minimization Plan
Fort Riley

15. NUMBER OF PAGES
170

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Foreword

This study was conducted for the Fort Riley, KS, Directorate of Environment and Safety under Military Interdepartmental Purchase Request (MIPR) No. DEHM910097; Work Unit "Hazardous Waste Minimization Study." The technical monitor was Larry Ness, AFZN-ES-P.

The work was performed by the Environmental Engineering Division (EP) of the Environmental Sustainment Laboratory (EL), U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. Edgar Smith is Acting Chief, CECER-EP, and William Goran is Chief, CECER-EL. The USACERL technical editor was Gloria J. Wienke, Information Management Office.

LTC David J. Rehbein is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

Contents

List of Tables

Tables

1 Introduction

Background

Waste minimization is the process of reducing the net outflow of hazardous solid, liquid, and gaseous effluents from a given source or generating process. It involves reducing air emissions, contamination of surface and ground water, and land disposal by means of source reduction, recycling processes , and treatment leading to complete destruction. Transferring pollutants from one medium to another (e.g., from water to air) by treatment processes is not waste minimization.

On November 8, 1984, the U.S. Congress signed into public law[1] the Hazardous and Solid Waste Amendments (HSWA) act establishing a national policy on waste minimization. HSWA required the U.S. Environmental Protection Agency (USEPA) to issue regulations that began the process of implementing the 1984 amendments to the Resource Conservation and Recovery Act (RCRA).[2] Among the Federal regulations is a requirement that every generator of hazardous wastes (HW) producing in excess of 2205 pounds (lb)[3] per month certify, when hazardous wastes are manifested (listed on a tracking document), that a hazardous waste minimization program is in operation.[4] Generators are required to submit biennial reports to the USEPA that describe efforts taken to reduce the volume and toxicity of waste generated during the year. Federal regulations issued in October 1986 clarify the status of small quantity (220 to 2205 lb/month) generators (SQG) of hazardous waste.[5] SQGs are required to make a "good faith" effort to minimize hazardous waste generation and implement the best available treatment, storage, or disposal alternative economically feasible.

The more restrictive regulations, high treatment/disposal expenses, and increased liability costs prompted private industry and several government agencies to critically examine means that will lead to prevention of pollution as opposed to end-of-pipe treatment methods. Waste minimization is economically beneficial to Army

---

1 Public Law 98-616, *Hazardous and Solid Waste Amendments* (1984).

2 Public Law 94-480, *Resource Conservation and Recovery Act* (1976).

3 Regardless of the units of measure used in source documents, all measurements have been converted to English units. Metric conversions are on p 128.

4 40 CFR 261, *Identification and Listing of Hazardous Waste*, and 40 CFR 262, *Standards Applicable to Generators of Hazardous Wastes* (1985).

5 Federal Register, Vol 51, No. 190 (October 1986), pp 35190-35194.

installations. Some of the cost savings realized by minimizing wastes result from reduced transportation and disposal costs for offsite disposal; reduced compliance costs for permits, monitoring, and enforcement; reduced onsite treatment costs; reduced onsite storage and handling costs; lower risk of spills, accidents, and emergencies; lower long term liability and insurance costs; reduced raw materials costs; reduced waste generation fees; reduced effluent costs and assessments from local sewage treatment plants; reduced production costs through better management and efficiency; and reduced operation and maintenance costs.

In fiscal year (FY) 1987, the Army directly paid (through a centrally funded process) the Defense Logistics Agency (DLA) $17.5 million for disposal of only 15 percent of the total wastes generated by Army installations.[6] The DLA, through its Defense Reutilization and Marketing Offices (DRMOs) located in several regions, was responsible for disposal of most categories of hazardous waste generated by the installations. The installations do not have a separate funding account for waste disposal and therefore do not realize the responsibility for waste generation and the cost of disposal. Beginning in FY 1990, the accounting process for waste disposal will be decentralized to provide a strong economic incentive to reduce waste generation.[7] The installations will have to pay the waste disposal costs from their operation and maintenance budget.

In December 1985, the Joint Logistics Commanders (JLC) established the following Department of Defense (DOD) policy:[8]

> The generation of hazardous waste (HW) at Department of Defense activities is a short- and long-term liability in terms of cost, environmental damage, and mission performance. A HW minimization program shall be developed by each service and shall contain the basic concepts in this directive.

Recognizing the liabilities of improper disposal and the advantages of waste minimization, JLC set a DOD-wide goal of 50 percent reduction in hazardous waste generation by 1992, based on the baseline generation in 1985. The Department of the Army is following this DOD goal and has established a policy applicable to all Active Army, Reserve, and National Guard installations.[9]

---

6 V.J. Ciccone and Associates, Inc., *Program Status Report: Department of the Army Hazardous Waste Minimization*, (U.S. Army Environmental Office, August 1988), p 43.

7 Office of the Assistant Chief of Engineers, "Hazardous Waste Disposal Funding," DAEN-ZCP-B Memorandum (Department of the Army, 28 October 1988).

8 Joint Logistics Commanders, "Hazardous Waste Minimization Program," Memorandum to the Deputy Secretary of Defense (12 December 1985).

9 *Hazardous Waste Minimization (HAZMIN) Policy* (Department of the Army, 1989).

Army installations are like small cities with a variety of activities that generate pollution within their boundaries. Unlike civilian cities, where there are many SQGs, each installation as a whole (and its Commander) is a generator held responsible for complying with regulations and reducing pollution from all the activities within its boundaries. Environmental protection must be made a primary concern of every employee on an installation. Everyone must make an effort to protect air, water, and land from industrial and chemical contaminants. Pollution prevention pays not only in terms of complying with regulations, saving in disposal/treatment costs, reducing liability and improving public image, but also in maintaining the good health and welfare of all people.

Each installation is responsible for implementing a hazardous waste minimization (HAZMIN) plan and each employee, military and civilian, is responsible for following the plan. To comply with both the letter and the spirit of the law, Fort Riley contracted the U.S. Army Construction Engineering Research Laboratories (USACERL) to prepare a HAZMIN plan for the installation.

Objective

The objective of this research was to develop a hazardous waste minimization plan for Fort Riley, KS, to include the actions necessary to accomplish reduction in volume and toxicity of hazardous wastes generated.

Approach

The approach used in previous HAZMIN studies performed by USACERL was modified to be appropriate for Fort Riley. The following approach was used to develop the plan:

1. Discuss HW generation patterns and disposal procedures with Fort Riley environmental personnel.
2. Visit major HW generating sites and a representative sample of common generating sites to see HW generating processes and discuss collection and disposal procedures. Tour DRMO HW storage facilities.
3. Gather information on HW generation rates and disposal costs from DRMO disposal records for the calendar years 1989, 1990, and 1991.
4. Prioritize waste streams by criteria such as composition, quantity, degree of hazard, method and cost of disposal, and potential to minimize.
5. Identify and prioritize minimization options for major waste streams.

6. Conduct feasibility and economic analyses of minimization options.
7. Prepare the final plan.

Scope

Although an attempt was made to quantify all the hazardous wastes generated at Fort Riley, a study of the mass balance of chemicals entering and wastes leaving the installation (which allows development of strategies for waste minimization) could not be completed because of lack of information on hazardous materials procurement.

Mode of Technology Transfer

The HAZMIN plan (Appendix A) will be presented to Fort Riley for implementation. The recommendations that have been made should be incorporated in the installation policies and regulations.

2 Hazardous Waste Minimization

The HSWA requires generators of hazardous wastes to certify that they have a waste minimization program. Every waste shipment manifest (or tracking document) is accompanied by the following declaration, in compliance with Section 3002(b) of HSWA:

> The generator of the hazardous waste has a program in place to reduce the volume and toxicity of such waste to the degree determined by the generator to be economically practicable; . . .

HSWA Section 3002(a) requires the generators of hazardous wastes to submit a biennial report, including their efforts to reduce the volume and toxicity of wastes generated. HSWA Section 3005(h) requires facilities that treat, store, or dispose of hazardous wastes to submit annual reports accompanied by similar declarations on waste minimization.

The HSWA also established a national land disposal restriction program by developing a schedule for banning all hazardous wastes from land disposal by May 1990. In November 1986, USEPA issued the first set of restrictions regarding land disposal of hazardous wastes.[10] These restrictions prohibited land disposal of untreated and concentrated spent solvents. Deadlines for banning land disposal were extended for other solvent wastes because it was felt that sufficient nationwide capacity for treatment did not then exist. In the near future, commercial land disposal may be available only to hazardous waste residues from treatment processes. In addition, generators may be held liable for environmental contamination. Therefore, alternatives to land disposal are necessary.

Minimization includes any reduction in hazardous waste generation and any activities that result in either a reduction in the total volume or quantity of hazardous wastes, or a reduction in the toxicity of hazardous wastes produced, or both, as long as the activities are consistent with the national goal minimizing present and future threats

---

[10] Federal Register, Vol 51, No. 190.

to the environment.[11] By this definition, treatment options such as incineration are considered HAZMIN techniques. HAZMIN, therefore, can be achieved by:

1. Source Reduction: reducing or eliminating waste generation at the source, usually within a process or by an action taken to reduce the amount of waste leaving a process,
2. Recycling Onsite/Offsite: using a waste as an effective substitute for a commercial product, or as an ingredient or feedstock in a process. Recycling also implies reclaiming useful constituent fractions from a waste or removing contaminants, allowing the waste to be reused, or
3. Treatment: eliminating the hazardous characteristics of a waste to make it nonhazardous to human health and the environment.

The previous list represents the hierarchy that should be used in a waste minimization process. The small amount of residue (e.g., ash) from the process will require "ultimate" disposal (e.g., landfill burial). Various waste minimization techniques are discussed in detail in the following sections. These techniques can be divided into three HAZMIN categories. Maximum waste reduction is usually achieved by using the best combination of suitable techniques from all three categories.

Source Reduction

Source reduction is at the top of the hierarchy and is the preferred solution to the problem of hazardous wastes. All wastes have some potential to be minimized by using better operating practices, product/material substitution, and process changes. Source reduction eliminates the need for storage, transportation, treatment, and residue disposal, and associated liabilities.

Better Operating Practices

Better operating practices include the simplest source reduction measures such as reducing spillage and leaks, inventory control, employee education/training and supervision, and better materials/wastes handling practices (e.g., segregation). Experience has shown that education and training programs in safety and hazardous materials/wastes management can be very effective. One approach to good housekeeping is to automate or computerize continuous processes, thereby decreasing human involvement and errors. Waste segregation is an extremely important housekeeping

---

[11] *Minimization of Hazardous Waste. Executive Summary and Fact Sheet,* EPA/530/SW-86/033A (U.S. Environmental Protection Agency [EPA], Office of Solid Waste, 1986).

practice that should be incorporated into the work standard. The USEPA's "mixture rule" is under review, but as it is currently enforced, mixing a minute quantity of hazardous waste with a large quantity of nonhazardous waste generates a large quantity of hazardous waste that has to be reported and properly disposed of. Therefore, wastes should never be mixed (e.g., solvents and oils, trash and solvents/oils, gasoline and solvents, etc.). Also, the purity of the waste determines its recyclability (discussed in the following section). Combining dissimilar wastes reduces the chance of recovering either one of them. By using waste segregation and improved handling, most generators could considerably reduce the quantities of wastes generated.

Inventory control is perhaps the most critical and effective better operating practice for HAZMIN. It is a low-cost and easily implementable method that is popularly used in many industries.[12] The quantities of wastes generated can be minimized by reducing the amount of excess material in stock and the amount used in any process or operation. Reduced stocks will also minimize the amount of material that must be disposed of due to expired shelf life. Controlling the purchase of raw materials is the first step in inventory control. Standard operating procedures that allow local or Federal supply system purchase of only approved materials should be established. New materials must be approved before purchase. A tracking system should be established to ensure that all the materials purchased are used properly. Such a materials "manifest" system is a tool that is useful not only in minimizing waste generation but also in complying with the Community "Right-To-Know" law.[13]

Product/Material Substitution

Product/material substitution is a major category of source reduction. Most hazardous wastes are so categorized because they result from processes that use hazardous materials as input or in an intermediate step. Product substitutions are necessary to minimize the environmental impacts of some products (e.g., pesticides such as DDT, 2,4,5-T, etc.) and associated wastes. Therefore, use of nonhazardous or less hazardous products as substitutes is recommended. An example of product substitution is replacing cadmium plated products with zinc or aluminum plated products in metal finishing operations.

---

[12] G.E. Hunt and R.N. Schecter, "Minimization of Hazardous-Waste Generation," in *Standard Handbook of Hazardous Waste Treatment and Disposal*, H.M. Freeman Ed. (McGraw Hill, New York, NY, 1989), pp 5.3-5.27; D. Huisingh, *Profits of Pollution Prevention: A Compendium of North Carolina Case Studies* (North Carolina Board of Science and Technology, Raleigh, NC, 1985).

[13] Public Law 99-499 Title III, *Superfund Amendments and Reauthorization Act* (1986).

Material substitution can also be viewed as a change in a process that involves using nonhazardous or less hazardous input or raw material, or a material with few impurities. Less hazardous materials with fewer impurities can reduce the likelihood of generating high volumes of hazardous wastes. Some examples of material substitution are replacing chlorinated solvents (e.g., trichloroethylene [TCE], 1,1,1-trichloroethane) with hot caustic solutions or detergents in degreasing operations; using non-cadmium pigments in ink manufacture; and replacing cyanide formulations with non-cyanide formulations in cadmium electroplating baths.[14]

One major form of product/material substitution is "aqueous" substitution — the use of water-based materials as inputs or products in a process. Many aqueous alternatives have been developed by the chemical industries. Some examples of aqueous substitution are replacing organic liquids (e.g., TCE, Stoddard solvent, xylene, toluene, etc.) with water-based products (e.g., Citrikleen, Histoclear, etc.) in metal cleaning and degreasing operations; replacing petroleum-based fluids with water-based fluids in metalworking and machining operations; substituting solvent-based ink with water-based ink in the printing processes; and using a water-based developing system instead of a solvent-based system in the manufacture of printed circuit boards.[15]

Process Changes

Some generators will have to consider either improvements in the manufacturing process or major changes in the technological processes to achieve waste reduction. Process change is a category of source reduction and includes source control. Source control implies examination and reevaluation of the processes that generate hazardous waste. Process optimization and increased efficiency were terms commonly used in source control projects to obtain the best quality product. Not much attention was paid to the waste. The concept of source control, therefore, is not new. Optimizing a process or increasing its efficiency also reduces the quantities of wastes generated. Process change or source control can be further divided into three areas: process/equipment modifications, improved controls, and energy/water conservation.

Process/equipment modifications will require that operating/manufacturing processes and equipment used for waste minimization be redesigned. Some examples of process modifications are: using dry plastic media blasting instead of wet chemical stripping (with methylene chloride, hot caustics, etc.) to remove paint from metallic substrates, replacing concurrent rinsing with countercurrent rinsing in metal plating and surface

[14] *Alternative Technology for Recycling and Treatment of Hazardous Wastes*, Third Biennial Report (California Department of Health Services, Alternative Technology and Policy Development Section, 1986).

[15] *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

finishing operations, and retrofitting the existing chrome-plating processes with equipment that reduces the discharge of rinsewater to almost zero.[16]

Improving controls could also be included under "better operating practices." It implies proper control of processes or equipment to reduce emissions and waste generation. Conserving energy/water by controlling the heat input and reducing the amount of rinse/process water used can reduce emissions, solid wastes, and wastewater.

Recycling Onsite/Offsite

After all source reduction techniques have been examined for a particular waste stream, recycling options, both onsite and offsite, should be considered. Three types of onsite recycling operations are available: (1) reuse of waste in the same process (e.g., continuous recycling of rinsewaters in plating/finishing operations, recycling of tetrachloroethylene in dry cleaning operations), (2) use of the waste in a different process (e.g., using waste battery acid as a neutralizing agent in an industrial wastewater treatment plant), and (3) processing the waste to produce a reusable product (e.g., distilling solvents, burning used oil for heat content, etc.).[17] Offsite recycling includes methods used to process the waste to produce a usable product (e.g., re-refining waste oil, reclaiming lead from lead-acid batteries, recovering silver from fixing bath solutions, incinerating hazardous wastes for heat content, etc.).

Recycling of hazardous wastes is encouraged by the Federal and State governments. Hazardous waste generators must explore all recycling opportunities for wastes whether or not the generation is reduced. Industrial recyclers are available for a number of wastes. Recyclable wastes include: unused commercial chemical products, halogenated solvents, oxygenated solvents, hydrocarbon solvents, petroleum products (including oils and hydraulic fluids), pickling liquor, unspent acids and alkalis, and selected empty containers.[18] Some offsite programs recycle batteries, mercury, and drums. Offsite recycling is also a major part of the program called "solvent leasing." In this program, a generator will lease process equipment. The equipment owner provides clean solvent and is responsible for removing and recycling used solvent.

An offsite recycling method that needs to be evaluated by DLA and DRMOs is the use of waste exchanges to recycle wastes. Waste exchanges are operations that engage or

---

[16] *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

[17] *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

[18] *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

assist in transferring wastes and information concerning wastes. They help generators develop effective waste minimization programs and comply with legislative and regulatory requirements. A list of waste exchanges operating in North America is provided in Table 1.[19] Some of these organizations are waste information "clearinghouses" and others are waste material exchanges. The information exchanges are usually nonprofit organizations that provide information about the availability and demand of waste materials. Material exchanges act as agents or brokers, and usually take the waste materials, process them, and market them for profit.

Treatment

Treatment of hazardous wastes should be the last minimization choice; after source reduction and recycling, but before "ultimate" disposal. Treatment alternatives must be considered only if source reduction and recycling are not feasible or economically practical. A treatment process (1) destroys or detoxifies a hazardous waste, to a material safe for disposal, (2) concentrates or reduces the volume of wastes for safer handling and disposal, or (3) immobilizes the hazardous components to keep them from the environment. Generators of large amounts of hazardous wastes usually treat the wastes onsite; generators of small amounts of hazardous wastes use offsite treatment facilities. With the increased availability of commercially packaged treatment units, generators may opt to treat wastes onsite. A hazardous residue requiring "ultimate" disposal may still be generated. Treatment processes include neutralization, filtration, evaporation, incineration, and precipitation. Acids, bases, and plating wastes are some of the waste streams that can be treated readily.

Four broad categories of treatment technologies (physical, chemical, biological, and thermal) are applicable to all waste streams. Physical treatment techniques, generally involving phase separation (e.g., solids from liquids), include: separation techniques such as centrifugation, clarification, coagulation, decantation, encapsulation, filtration, flocculation, flotation, foaming, sedimentation, thickening, and ultrafiltration; and specific component removal techniques such as adsorption, blending, catalysis, crystallization, dialysis, distillation, electrodialysis, evaporation, magnetic separation, leaching, ion exchange, liquid-liquid extraction, reverse osmosis (RO), stripping, and sand filtration.[20] Some of the physical treatment techniques can be readily used as pretreatment steps (e.g., filtration, sedimentation, etc.) before onsite recycling of wastes and also as a part of better housekeeping practices.

---

19 Tables appear at the end of each associated chapter.

20 *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

Chemical treatment techniques that use the differences in chemical properties of substances include mound adsorption, fixation, oxidation, precipitation, reduction, chlorination, cyanide destruction, degradation, detoxification, ion exchange, neutralization, ozonation, and photolysis.[21] Biological treatment techniques include activated sludge digestion, aerobic processes, composting, trickling filtration, and waste stabilization.[22] Biological treatment processes rely on microorganisms (bacteria, fungi, etc.) to decompose and/or bioaccumulate the contaminants in wastes.

As a HAZMIN technique, treatment, unlike source reduction or recycling, has legal (or RCRA) implications. A permit must be obtained for treatment of hazardous wastes. Only elementary neutralization (e.g., laboratory acids/bases neutralization) and enclosed wastewater and other treatment units are exempt from permitting requirements.[23]

HAZMIN Assessment

The HAZMIN assessment procedure and development of the plan (Appendix A) was based on the methods described in *EPA (Environmental Protection Agency) Manual for Waste Minimization Opportunity Assessments*[24], and other references.[25] The assessment protocol is attached in Appendix B.

Development of a successful HAZMIN program contains four critical phases: planning and organization, assessment, feasibility analysis, and implementation. USACERL was involved in the assessment and feasibility analysis phases at Fort Riley.

The first task in the assessment phase is to gather all the available information pertaining to hazardous materials procurement, waste generation and disposal, and operating procedures. Second, prioritized and selected waste streams for assessment. Conduct a site visit of hazardous waste generating operations to interview supervisors, foremen, and operators; observe housekeeping practices; inquire about standard operating procedures; and gather information about levels of administrative controls.

---

21 *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

22 *Alternative Technology for Recycling and Treatment of Hazardous Wastes.*

23 40 CFR 260, *Hazardous Waste Management System: General* (1985).

24 *EPA (Environmental Protection Agency) Manual for Waste Minimization Opportunity Assessments*, EPA/600/2-88-025 (USEPA, Hazardous Waste Engineering Research Laboratory, 1988).

25 R.H. Hemstreet, "How to Conduct your Waste Minimization Audit," in *Waste Minimization Manual*, (Government Institutes, Inc., Rockville, MD, 1987), pp 61-75; M.E. Resch, "Hazardous Waste Minimization Audits using a Two-Tiered Approach," *Environmental Progress*, Vol 7 (1988), pp 162-166; M. Drabkin, C. Fromm, and H. M. Freeman, "Development of Options for Minimizing Hazardous Waste Generation," *Environmental Progress*, Vol 7 (1988), pp 167-173.

Waste minimization options are then evaluated. The most promising options are selected for detailed evaluation.

In the feasibility analysis phase, the technical and economic feasibility of selected minimization options is evaluated. This phase includes the installation information and data gathered (Chapter 3), waste minimization techniques for the various types of sources and wastes (Chapters 4 through 10), and economic analysis of minimization options for select waste streams (Chapter 11).

Fort Riley should implement the HAZMIN plan according to methodology presented in Chapter 12. Successful implementation of the plan will require command support and commitment. Continuance of the HAZMIN program in the future will require constant evaluation of the goals, reassessment of generators, and developing newer/better procedures for minimizing wastes.

Table 1. List of waste exchanges.

Alberta Waste Materials Exchange
4th Floor Terrace Plaza
4445 Calgary Trail South
Edmonton, Alberta
CANADA T6H 5R7
(403) 450-5461

California Waste Exchange
Department of Health Services
Toxic Substances Control Division
714 P Street
Sacramento, CA 95814
(916) 324-1807

Canadian Inventory Exchange*
900 Blondin
Ste-Adele, Quebec
CANADA J0R 1L0
(514) 229-6511

Canadian Waste Materials Exchange
Ontario Research Foundation
Sheridan Park Research Community
Mississauga, Ontario
CANADA L5K 1B3
(416) 822-4111

Enkam Research Corporation*
P.O. Box 590
Albany, NY 12202
(518) 436-9684

Georgia Waste Exchange*
c/o America Resource Recovery
P.O. Box 7178, Station A
Marietta, GA 30065
(404) 363-3022

Great Lakes Regional Waste Exchange
470 Market Street, S.W.
Suite 100-A
Grand Rapids, MI 49503
(616) 451-8992

Indiana Waste Exchange
P.O. Box 1220
Indianapolis, IN 46206
(317) 634-2142

Industrial Materials Exchange Service
2200 Churchill Road
IUSEPA/SLPC-24
Springfield, IL 62706
(217) 782-0450

Industrial Waste Information Exchange
New Jersey Chamber of Commerce
5 Commerce Street
Newark, NJ 07102
(201) 623-7070

Manitoba Waste Exchange
c/o Biomass Energy Institute, Inc.,
1329 Niakwa Road
Winnipeg, Manitoba
CANADA R2J 3T4
(204) 257-3891

Montana Industrial Waste Exchange
Montana Chamber of Commerce
P.O. Box 1730
Helena, MT 59624
(406) 442-2405

Northeast Industrial Waste Exchange
90 Presidential Plaza, Suite 122
Syracuse, NY 13202
(315) 422-2405

Resource Recovery of America**
P.O. Box 75283
Tampa, FL 33675-0283
(813) 248-9000

South Waste Exchange
Urban Institute
UNCC Station
Charlotte, NC 28223
(704) 547-2307

Southern Waste Information Exchange
P.O. Box 6487
Tallahassee, FL 32313
(904) 644-5516

Tennessee Waste Exchange
Tennessee Manufacturers and Taxpayers Association
226 Capitol Blvd., Suite 800
Nashville, TN 37219
(615) 256-5141

Wastelink, Division of Tenecon Associates*
P.O. Box 12
Cincinnati, OH 45174
(513) 248-0012

Western Waste Exchange
ASU Center for Environmental Studies
Krause Hall
Tempe, AZ 85287
(602) 965-1858

Zero Waste Systems**
2928 Poplar Street
Oakland, CA 94608
(415) 893-8261

*For-profit information exchange.
**Material waste exchange.

3 Fort Riley Hazardous Waste Generation

Fort Riley

"The early history of Fort Riley is closely tied to the movement of people and trade along the Oregon and Santa Fe Trails. During the 1850's, military posts were established at strategic points to provide protection along these arteries of emigration and commerce. Originally called Camp Center, the fort changed its name to Riley in honor of Major General Bennett C. Riley who had led the first military escort along the Santa Fe Trail in 1827.

"Prior to the Civil War, cavalry units stationed at Fort Riley were used to "police" the recently opened Kansas Territory because of tension and bloodshed between pro and anti-slavery factions. During the Civil War, units at Riley were dispatched to Union Armies in the East and were replaced by state units. Shortly after the conclusion of the Civil War, Brevet Major General George A. Custer arrived to take command of the 7th Cavalry. This unit was mustered-in at Fort Riley to protect workers constructing the Union Pacific Railroad across Kansas.

"[As the old frontier became more settled], many forts . . . were closed. However, Riley escaped this fate when Lt. General Philip Sheridan urged that the fort be the cavalry headquarters of the Army."[26]

Since then, Fort Riley has become an integral part of the United States military. Soldiers from Fort Riley have served in World Wars I and II, Korea, Vietnam, and the Gulf War in Saudi Arabia and Kuwait. Today Fort Riley is home to the 1st Infantry Division (Mechanized). The Division includes two maneuver brigades, a combat aviation brigade, two field artillery battalions, and many combat support and combat service support units.

Fort Riley is part of the U.S. Army Forces Command (FORSCOM). FORSCOM installations are generally administrative, hospital/medical, or active troop installations. Various quantities of hazardous wastes are generated at these installations, depending on their respective missions. Table 2 shows estimated quantities of

[26] This information was taken form a brochure on the U.S. Cavalry Museum which is located at Ft. Riley.

hazardous waste generated at 22 installations.[27] Fort Riley's estimated hazardous waste generation was 18.6 tons per year for 1985, 1986, and 1987. These are wastes that were turned in to the DRMO for proper disposal. Table 2 does not include waste oil that is being recycled by an offsite contractor for heat recovery, burning of gasoline and aviation fuel at the fire training area, contaminated water treated at the wastewater treatment plant, hazardous air emissions, and so on.

Data on Fort Riley's hazardous waste generation used in this study were collected from the Fort Riley DRMO disposal records for 1989, 1990, and 1991, and from the cleaning solvent service contract and used oil disposal log. The DRMO hazardous waste disposal records indicate that Fort Riley disposed of approximately 60 metric tons in 1989, 85 metric tons in 1990, and 62 metric tons in 1991. These numbers are significantly higher than the disposal rates listed in the previous report. There are several possible explanations for the discrepancies in the numbers: (1) Fort Riley's waste generation rates were underestimated in the previous study, (2) Fort Riley may now have more waste streams classified as hazardous than they did at the time of the previous study, or (3) Fort Riley's hazardous waste generation rates are increasing. The answer may be a combination of these reasons. Whatever the explanation, it appears to be an alarming trend that Fort Riley's environmental personnel should be aware of when implementing waste management and minimization plans. The significant increase in 1990 disposal is most likely due to the substantial vehicle servicing and painting that preceded and followed the deployment to Saudi Arabia for Desert Shield/Desert Storm.

Source Types

Many different source types at Fort Riley generate hazardous wastes. It is necessary to understand each source type and the wastes generated before attempting to minimize the total quantities generated. There are several major waste streams and a large number of miscellaneous small quantity waste streams at Fort Riley.

Motor Pools and Vehicle Maintenance Facilities (MPVM) and Aviation Maintenance Facilities (AMF)

FORSCOM installations typically have a variety of motor pools and vehicle maintenance facilities for tactical and nontactical vehicles. Nontactical vehicle motor pools are used to service and maintain all administrative vehicles (e.g., cars, vans, trucks, etc.), engineering maintenance vehicles (e.g., trucks, bulldozers, forklifts, etc.), and

[27] V.J. Ciccone & Associates, Inc., p C-4.

grounds maintenance vehicles (e.g., tractors, mowers, etc.) on the installation. Servicing and maintenance of tactical vehicles is performed at various troop and tactical vehicle motor pools. Tactical vehicles can be divided into track-laying vehicles (e.g., self-propelled howitzers, guns, mortars, armored personnel carriers, etc.) and wheeled vehicles (e.g., cargo trucks, ambulances, truck tractors, wreckers, etc.). Most FORSCOM installations also have aviation maintenance facilities for helicopters and airplanes. Fort Riley has 23 MPVM facilities, 6 AMF, 1 TOE direct support maintenance building, and 1 consolidated maintenance facility.

Various levels of services are performed on the vehicles at each MPVM and AMF. Included in the services are periodic maintenance (e.g., fluids change, tuneup, etc.), transmission maintenance, engine repair, brake servicing, battery repair/servicing, front-end alignment, and unique repairs (as required, for different tactical vehicles or aircraft). The typical repair operations that use hazardous materials and generate hazardous wastes are oil and grease removal, engine parts and equipment cleaning, solution replacement, paint stripping, and painting (discussed later under *Paint Shops*). Some of the equipment commonly used at MPVMs and AMFs are solvent sinks (parts cleaning), caustic baths (for engine and radiator cleaning), and spray equipment.

Some general categories of hazardous materials used at MPVMs and AMFs are batteries, oils, petroleum distillates, mineral spirits, varsol, halogenated solvents, aromatic hydrocarbons, oxygenated hydrocarbons, acids, and alkalis. A variety of nonhazardous materials (e.g., sorbent, rags, etc.) are used in conjunction with these hazardous materials and can become hazardous wastes if they are contaminated with hazardous materials.

Industrial Maintenance, Small Arms Shops (IMSS)

The Directorate of Logistics (DOL) and Directorate of Environment and Safety (DES) are usually responsible for the major IMSS on a FORSCOM installation. The DOL and DES industrial operations shops repair and maintain everything from office machines and furniture to small arms and nuclear weapons. Tenant units may also have industrial operations shops conducting maintenance and repair on a small scale.

Industrial shops typically use vapor degreasers for degreasing operations; caustic dip tanks for cleaning iron and aluminum parts; battery recharging and neutralization tanks for battery recharge, repair, and replacement; painting and paint-stripping equipment (see *Paint Shops* section); and phosphoric/chromic acid tanks for small arms refinishing. These operations use hazardous materials and generate hazardous wastes. Unserviceable lead-acid batteries are drained at Fort Riley and the acid is turned in to the Fort Riley DRMO as a hazardous waste.

Many different kinds of hazardous materials are typically used at these IMSSs, including halogenated solvents (TCE, 1,1,1-trichloroethane), paint thinners (xylene, toluene, etc.), corrosive chemicals (alkalis, acids, etc.), and radioactive materials.

Paint Shops (PS)

A FORSCOM installation has painting operations ranging from spray painting with cans to painting large vehicles. DES paint shops have the responsibility of painting buildings, preparing signs, and painting the fleet of grounds maintenance and other vehicles. DOL paint shops have large paint booths for painting tactical and nontactical vehicles. The only hazardous waste generated by spray painting with cans, which is common throughout the installation, is the empty cans with wet or dried paint residue. Paint thinners used in large painting operations result in generation of large quantities of hazardous waste. Filters from paint booths may also have to be disposed of as hazardous waste.

Photography, Printing, and Arts/Crafts Shops (PPAS)

FORSCOM installations have photography and print shops that conduct a wide range of printing operations, including standard forms, brochures, pamphlets, newsletters, and circulars. Also, the shops perform image and plate processing. Image processing is a method for preparing artwork that includes typesetting and photoprocessing. The photographic process produces a negative with the light portions of the photographed object filled with deposits of silver. Among the steps involved in a photographic process are developing, fixing, washing, and reducing/intensifying. Wastes produced by the photographic processes include chemical wastes, bath dumps, and wastewaters containing photoprocessing chemicals, silver, and other substances.

The printing process requires an image carrier (manual, mechanical, electrostatic, or photomechanical) that takes the ink from a roller and transfers it to a rubber blanket. The image is then transferred from the rubber blanket to a paper. Wastes produced from the printing process include waste inks, trash, used plates, used ink containers, damaged or worn rubber blankets, waste press oils (lubricating oils), cleanup solvents, and rags.

Small quantities of a number of different wastes are generated by the PPAS. Developer and toner wastes are generated in the largest quantities. Silver is recovered from these solutions at Fort Riley. Other wastes are bleach, uralite, electrostatic ink and solution, and adhesive.

Hospitals, Clinics, and Laboratories (HCL)

A typical FORSCOM installation has at least one hospital (or medical center) providing full medical and dental services for active duty and retired military personnel and dependents on the installation. Each hospital has many clinics supporting different medical departments (anesthesiology, dermatology, internal medicine, obstetrics and gynecology, pathology, radiology, surgery, urology, etc.). Each department has laboratories that use hazardous materials and generate hazardous wastes. An installation may have teaching facilities (e.g., Institute for Dental Research) and laboratories for training personnel belonging to other medical activities in the military services. Other dental and veterinary clinics and facilities may also be located on the installation.

Fort Riley is host to the Irwin Army Community Hospital. The fort also has three dental clinics and one veterinary clinic. The preventive medicine department of the hospital is responsible primarily for the safety and security of medical staff and patients who may be exposed to hazardous materials/wastes and emissions. Many hazardous chemicals and radioactive materials are used in hospitals, clinics, and laboratories. The wastes include chemical waste, infectious solid waste, noninfectious waste, pharmaceutical waste, and radioactive waste.

Other Source Types

Other source types at a typical FORSCOM installation include heating and cooling plants, laundry and drycleaning facilities; sanitary landfills; wastewater treatment plants; troop units; industrial wastewater treatment plants; fire departments; hazardous waste storage facilities; petroleum, oils, and lubricants (POL) storage yards; golf courses; grounds maintenance/garden shops; entomology shops; electrical maintenance shops; storage warehouses; water treatment plants; and other miscellaneous sources unique to each installation.

Hazardous and Controlled Waste Management at Fort Riley

Hazardous and controlled wastes must be disposed of within 90 days of the start of collection. Fort Riley's procedure for turning in hazardous and controlled wastes is as follows:

1. Unit/activity prepares 1348-1s and containers for turn in as per Fort Riley HWSOP.

2. After making an appointment with DRMO, 239-0542, the unit/activity transports HM/HW to DRMO.
3. Unit/activity will assist DRMO overpack containers if necessary.
4. If during the turn in, a RCRA HW violation is noted, a standard memo and inspection form will be sent to the unit/activity's commander/director with a copy furnished to DES/Compliance. This feedback should be used to improve your HW program. However, repeat problems may be used by DES/Compliance to increase inspections.
5. If there are more than five hazardous material items to be turned in, please contact DRMO, 239-0542, who will arrange for a site visit which will ensure orderly turn-in.

Each unit has a designated hazardous waste manager who is responsible for monitoring the hazardous waste collection point at his or her unit to make sure the wastes are being stored properly. This person also is responsible for ensuring that the procedure just described is followed for hazardous waste turn-in to DRMO. In addition, DES Pollution Prevention has designated hazardous waste inspectors who periodically check the hazardous waste collection points to monitor compliance with hazardous waste storage regulations.

Hazardous and Controlled Waste Generation

Hazardous waste generation rates for Fort Riley were determined from DRMO hazardous waste disposal records for 1989, 1990, and 1991, and from waste oil disposal logs and the solvent service contract. The following sections describe the patterns and processes that generate the wastes. Although normally hazardous waste generation rates for individual units can be determined from the disposal records, this was not possible for the recent Fort Riley data because the Fort Riley DES instituted a hazardous waste amnesty turn-in as part of the deployment to Saudi Arabia for Desert Shield/Desert Storm. All hazardous waste turned in during this period was listed under the DES Department of Defense Activity Address Code (DODAAC). This prevented any analysis of waste generation patterns for specific units at Fort Riley.

The following sections describe the major waste streams generated at Fort Riley.

Cleaning Solvent Wastes

The majority of solvents used at Fort Riley are recycled under a service contract with Safety Kleen (SK). The SK contract amounts to approximately 37,000 gal of solvent per year at a cost to Fort Riley of about $131,500. The solvent is used in parts washing stations with reservoir capacities that vary from 5 to 45 gal. Every 4 to 12 weeks, depending on the location of each parts washing station and how the contract is set up, SK removes the solvent, cleans the parts washing station, refills the station with recycled solvent, and takes the used solvent to be recycled.

The Consolidated Maintenance Facility (Building 8100) is the largest solvent user at Fort Riley, accounting for approximately 9900 gallons per year of the SK contract. In addition to the standard parts washing stations, Building 8100 has one paint gun cleaning unit and three carburetor cleaning units that are serviced by SK.

In addition, there are small quantities of miscellaneous solvents used at Fort Riley as shown in Table 3. Most of these solvents are used for small wipe cleaning jobs. Only a few gallons a year of each type are disposed through DRMO for most of these solvents.

Batteries and Battery Electrolyte

Fort Riley generates a large number of unserviceable lead-acid vehicle batteries every year. The battery service shop in Building 8100 checks all batteries turned in by the units. If the batteries can still be used, they are recharged and returned to the units. If the batteries are unserviceable, the electrolyte (sulfuric acid) is drained from the batteries and stored in 55-gal drums. The terminal posts are removed from the empty batteries to identify them as unusable. The battery casings are then strapped to pallets and delivered to DRMO, where they are sold to a lead recycler. The battery acid also is transported to DRMO and disposed of as hazardous waste. DRMO personnel estimate that 300,000 lb of empty lead-acid battery casings are sold to the recycler annually. Table 4 shows the quantities of battery acid that were disposed of through DRMO as hazardous waste. Approximately 26,000 lb of sulfuric acid were disposed of in 1991.

Table 4 also shows the quantities of other types of batteries that were disposed of through DRMO as hazardous waste. The contractors in the aircraft maintenance building maintain a nickel- cadmium (NICAD) battery shop. The battery electrolyte (potassium hydroxide) is drained from unserviceable batteries and collected as hazardous waste. Since these batteries are smaller than lead-acid batteries and have a longer life, only a small quantity of this battery electrolyte is generated.

Paint and Painting Wastes

Table 5 shows the quantities and types of paint and painting wastes disposed of at Fort Riley. Vehicle spray-painting booths are located at the consolidated maintenance facility (Building 8100) and the aircraft maintenance facility (Building 727). These booths are used primarily for applying Chemical Agent Resistant Coatings (CARC) to military vehicles. Wastes generated from these operations include dried paint residue, solvents and thinners used for cleaning painting equipment, and filters to collect overspray. Building 8100 also has two other paint booths that are used for furniture finishing and small parts painting. Other painting operations at Fort Riley include building and office painting, sign painting, equipment painting, and furniture painting and finishing.

Large quantities of painting wastes were generated in 1990 and 1991 due to the deployment of the 1st Infantry Division to Saudi Arabia. All military vehicles that were deployed had to be repainted from forest green to tan. Because of this surge in hazardous waste generation, it is difficult to determine typical generation rates for paint and painting wastes from the available data.

Petroleum, Oils, and Lubricants (POL)

Used motor oil is drained from vehicles during routine maintenance at the MPVMs. Used motor oil is currently classified as a controlled waste, not as a hazardous waste, and is stored in underground storage tanks. The used oil often is drained directly to these tanks. Fort Riley has a contract for waste oil disposal with Midwestern Waste Oil of Oklahoma City, OK. When a unit's oil storage tank is nearing full, the unit calls DES Pollution Prevention to notify them. DES Pollution Prevention then calls the contractor to schedule pickup of the waste oil. The contractor's truck is equipped with a pumping mechanism and an oil-water separator. The contractor removes the oil and sludge from the storage tanks, transports it, and blends it with fuel for burning in the contractor's industrial boiler.

The quantity of waste oil generated at Fort Riley was determined from the contractor's waste oil log books. Table 6 shows Fort Riley's used motor oil generation rates for 1990 and 1991, as well as other POL that was disposed of as hazardous waste through the Fort Riley DRMO. Typical used motor oil generation at Fort Riley is probably somewhere between the 1990 and 1991 quantities. Deployment to Saudi Arabia probably accelerated the maintenance schedule on vehicles at the end of 1990 and early in 1991. This would increase the waste oil generation. The 1st Infantry Division was in Saudi Arabia for a significant portion of 1991, which probably reduced the quantity of waste oil generated at Fort Riley for that year.

Fuel that no longer meets specifications (off-spec fuel) is collected in drums and transported to the former POL point (Facility 1945) in Camp Funston for bulk storage before sale as a recyclable item.

Spent Antifreeze Solution

Antifreeze is drained from vehicles during routine maintenance at the MPVMs. Antifreeze is regulated as a controlled waste, so the current practice at Fort Riley is to collect the antifreeze in drums and transport it to the former POL point in Camp Funston for bulk storage prior to sale as a recycled item. Table 7 shows the quantities of used antifreeze generated at Fort Riley.

Other Hazardous Wastes

A large number of other hazardous wastes are generated at Fort Riley as shown in Tables 8 through 14. These tables are divided into the categories listed in the Fort Riley DRMO hazardous waste disposal contract. Table 8 shows that only small amounts of acute hazardous wastes are generated at Fort Riley.

Table 9 shows the quantities of corrosive acids and bases disposed of. Except for the decontaminating agent, DS-2, Fort Riley appears to have decreased acid and base disposal over the 3-year period studied. The large increase in DS-2 disposal is due to troops turning in unused quantities upon returning from the Gulf War. In 1993, all stocks of DS-2 were collected and sent to Pine Bluff Arsenal, AR. The only exception is the Crisis Response Force Division, which will maintain enough stock to support one division for immediate deployment.

Table 10 shows toxic hazardous waste generation. Most of the waste in this category is classified under one of the miscellaneous categories. In 1989, the 1900 lb of CLIN 2004 was mostly used paint filters that should have been included in the painting wastes table. In 1990, approximately 30 precent of the waste disposed of as CLIN 2004 was sand blasting residue, presumably from preparing vehicles for repainting prior to deployment of the troops. In 1991, CLINs 2001 and 2004 were primarily gas mask filters and chemical detection kits turned in after the troops returned from the Gulf War.

Table 11 shows ignitable hazardous waste generation. Again a large portion of the wastes listed in this table are under the miscellaneous categories. In 1989 and 1990, CLIN 2305 was primarily contaminated aviation turbine fuel. Parts from decontamination kits returned after the Gulf War made up most of CLIN 2301 in 1991. The 926 lb of CLIN 2304 disposed of in 1991 were mostly fuel icing inhibitor.

Tables 12, 13, and 14 show the quantities of pesticide wastes, photography wastes, and other miscellaneous wastes generated at Fort Riley. Relatively small quantities of all the wastes shown in these tables were generated. The DRMO disposal contracts that were in place during 1989 and 1990 required that all containers be listed separately from the items they contained. The current contract does not require this, so this waste stream is no longer tracked.

Other Controlled Wastes

Table 15 lists wastes that were disposed of through DRMO but are not classified as hazardous. Much of the CLIN 6005 is used antifreeze that should have been included in Table 7. Most of the fluctuations in the waste generation rates shown in Table 15 are due to the deployment and return of troops from the Gulf War.

Wastes Selected for Technical/Economic Analysis

The selection of wastes for technical and economic analysis was based on quantities of the wastes generated and preferences expressed by Fort Riley personnel. The wastes selected were used oils, spent antifreeze solution, spent cleaning solvent, and lead-acid batteries. Fort Riley personnel also were interested in looking into high-volume, low-pressure (HVLP) paint application and plastic media blasting (PMB) to replace sand blasting; however, the available information on the use of painting and sand blasting at Fort Riley was not sufficient to perform the analysis.

Table 2. Hazardous waste generation at FORSCOM installations.*

Installation	Quantity of Waste Generated (metric tons)			Quantity of Waste Generated Onsite (metric tons)			Quantity of Waste Generated Offsite (metric tons)		
	1985	1986	1987	1985	1986	1987	1985	1986	1987
A.P. Hill	n/a	0.6	810.7	n/a	0.6	810.7	0.0	0.0	0.0
Bragg	94.5	246.9	258.2	94.5	236.3	242.3	0.0	10.6	15.9
Buchanan	-	-	-	-	-	-	-	-	-
Campbell	181.1	42.3	83.7	181.1	42.3	83.7	0.0	0.0	0.0
Carson	37.5	29.1	28.9	37.5	29.1	28.9	0.0	0.0	0.0
Devens	1142.6	359.4	412.4	1142.6	359.4	412.4	0.0	0.0	0.0
Drum	18.4	89.0	0.7	18.4	89.0	0.7	0.0	0.0	0.0
Hood	46.5	238.5	129.8	46.5	223.0	129.6	0.0	15.5	0.3
Irwin	2090.4	1019.6	1224.1	2090.4	1019.6	1224.1	0.0	0.0	0.0
Lewis	n/a	214.3	668.3	n/a	187.3	649.3	n/a	27.0	19.0
McCoy	62.6	35.1	64.0	23.9	23.5	26.2	38.7	11.6	37.8
McPhearson	0.1	2.4	n/a	0.1	2.4	n/a	0.0	0.0	n/a
Meade	n/a	3.1	3.5	n/a	3.1	3.5	n/a	0.0	0.0
Ord	190.9	293.9	n/a	190.9	290.8	n/a	0.0	3.1	n/a
Polk	0.1	20.7	11.5	0.1	20.7	11.5	0.0	0.0	0.0
Presidio, SF	-	-	-	-	-	-	-	-	-
Richardson	21.1	16.4	4.8	21.1	16.4	4.8	0.0	0.0	0.0
Riley	30.0	31.0	51.0	30.0	31.0	51.0	0.0	0.0	0.0
Sam Houston	34.7	33.4	19.8	34.7	32.7	18.5	0.0	0.7	1.3
Sheridan	4.9	4.9	4.9	4.9	4.9	4.9	0.0	0.0	0.0
Stewart Hunter	7.7	302.4	445.8	7.7	302.4	445.8	0.0	0.0	0.0
Wainright	27.2	16.9	63.6	19.4	16.1	29.3	7.8	0.7	34.3
Total	3978.9	2987.5	4253.3	3932.4	2918.2	4144.8	46.5	69.2	108.6

* Source: V.J. Cicocone and Associates, Inc., p C-4.

Table 3. Solvents disposed through Fort Riley DRMO.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
4500	Solvents, Misc, in containers < 1 gal				60		6
4501	Solvents, Misc, in containers < 7 lbs			15		4	
4504	Solvents, Misc, (lbs)					59	
4505	Solvents, Misc, (gals)		32		377		300
4507	Acetone (dimethyl-ketone: 2-propanone)				55		2
4512	Cresylic Acid						5
4519	Methylene Chloride (methlyene dichloride: dichloromethane)			4			
4520	Methyl Ethyl Ketone (MEK)				1		13
4526	Tetrachloroethylene (perchloroethylene)				12		20
4527	Toluene (methyl-benzene: phenyl-methane)				8		14
4529	Trichloroethylene				15		10
4531	Trifluorotrichloroethane (1,1,2-Trichloro-1,2,2-Trifluoroethane)						9
4532	Xylene (dimethyl-benzene)		8		39		23
4535	Trichloroethane (1,1,2-)				137		1
4539	Acetone (dimethyl-ketone, 2-propanone)					7	
4552	Methyl Ethyl Ketone (MEK)				24		
4558	Tetrachloroethylene (perchloroethylene) (after 07/25/91)					8	
4564	Xylene (dimethyl-benzene) (after 07/25/91)					70	
4565	Freon (fluorocarbons)					34	
4595	Water, may be contaminated w/ trichloroethane, MEK, and/or solvents		5				
4597	Solvents, may have (but not limited to) water and petroleum products					13	
4710	Methylene chloride sludge						55
4715	MEK, may be contaminated				55		
4723	Carbon Remover with heavy metals				40		
4725	Mixed solvents, methylene chloride, trichloroethane, freon, and MEK				2		8
4731	Solvents, may have (but not limited to) water and petroleum products				58		1
4738	Ignitables, misc with any solvents restricted by C.23 (liquid and sludge)		330				
4752	Waste with any C.23 solvent(s) (lbs)	11		4			
4753	Waste with any C.23 solvent(s) (gals)				147		
5000	Solvents, misc (non C.23) in containers < 1 gal		1		20		
5005	Solvents, misc (non C.23) (gals)				540		
5007	PD-680		50		190		5
5010	Stoddard solvent				30		
5011	Dry Cleaning Solvent				619		95

Table 4. Batteries and battery electrolyte generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
500	Batteries, Misc	8500		1169		4098	
501	Batteries, Lithium-Sulfur-Dioxide	1678		1402		2282	
503	Batteries, Nickel Cadmium	9157		2516		4086	
504	Batteries, Mercury	114		106		149	
506	Batteries, Aid to Navigation (ATDN), potassium hydroxide and zintate					173	
1309	Battery Electrolyte (sulfuric acid) (before 07/25/91)		4607		3580		271
1333	Battery Electrolyte (sufuric acid) (after 07/25/91)					15,341	
1359	Sulfuric acid, contaminated with heavy metals, etc.					8537	

Table 5. Paint wastes generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
3100	Paint, Misc in containers < 1 gal				8		6
3101	Paint, Misc in containers < 7 lb	381				381	425
3104	Paint, Misc (lbs)			3732	45	811	
3105	Paint Misc (gals)		8		589		946
3108	Enamel				441		2016
3110	Lacquer		3		14		21
3121	Enamel					439	
3132	Paint Wastes (liquids, sludges or any combination)					198	
3141	Solvents and/or Thinners with (but not limited to) paint wastes					8732	
3142	Paint Removers					29	
3300	Paint wastes, may have oils, thinners, dirt, solvents, removers, strippers		5		324		292
3306	Paint waste, solid, (solidified paint, chips, filters, brushes, etc.)					6530	
3307	Paint wastes with (but not limited to) strippers, heavy metals, and acids						460
3310	Paint, partially solidified (solids, liquids, sludges, or any combination)			100			36
3312	Filters contaminated with paint wastes					1659	
4700	MEK and paint				81		
4701	Methanol, Toluene, Water, Paint		10		51		100
4704	Solvents and Thinners with (but not limited to) paint wastes		175		75		585
4705	Paint Removers				55		
4732	Paints, Misc with any solvents restricted by C.23 (liquid)		315	8	251		
4733	Paints, misc, with any solvent restricted by C.23 (liquid and sludge)			16			

Table 6. Petroleum, oils, and lubricants generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
----	Used Motor Oil*				182,248		95,340
3900	POL, misc, in containers < 1 gal						3
3901	POL, misc, in containers < 7 lbs					97	
3904	POL, misc (lbs)	62					
3905	POL, misc (gals)		220				57
3909	Naphtha (mineral spirits)				180		11
3911	Oil/Oil sludge from water separator or tank		150				26
3916	Diesel Fuel		3765		6523		590
3921	Oil, may have dirt, water, diesel fuel, thinners, solvents, paint, etc.				182		
3922	Hydraulic Fluid with (but not limited to) heavy metals and solvents		55				
3926	Oil, Synthetic				95		55
3930	Hydraulic Fluid		110		20		

* Used motor oil is reported for fiscal years 1990 and 1991. All other quantities are reported for calander years.

Table 7. Waste antifreeze generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
2121	Ethylene Glycol (anti-freeze) may have heavy metals, oils, dirt, water		1685		1447		
6120	Ethylene Glycol (diethylene glycol)					29487	

Table 8. Acute hazardous wastes generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
1	Acute Haz Waste, Misc, in Containers < 1 gal			1	1		
2	Acute Haz Waste, Misc, in Containers < 7 lb			1		7	2
17	Epinephrine (before 07/25/91)	25	30		7	6	2
23	Epinephrine (after 07/25/91)					8	

Table 9. Corrosive acids and bases generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
1300	Acids, Misc., in containers < 1 gal		1		2		1
1301	Acids, Misc. in containers < 7 lb					63	
1304	Corrosives Acids, Misc. (lbs)	2220		100		76	
1305	Corrosives Acids, Misc. (gals)		68		554		79
1317	Sulfuric				3		
1323	Ferric Chloride	300		266			
1341	Sulfuric Acid					1	
1562	Sulfuric acid, contaminated with heavy metals, paints, dirt, etc.						108
1563	Hydrochloric acid, contaminated with heavy metals, paints, dirt, etc.				5		9
1651	Corrosives Bases, Misc in containers < 1 gal		1		96	23	24
1652	Corrosives Bases, Misc in containers < 7 lb			247		50	
1655	Corrosives Bases, Misc (lbs)	1		435		576	
1656	Corrosives Bases, Misc (gals)		8		130	1	150
1659	Sodium Hydroxide (caustic soda) (lbs)					300	3
1660	Sodium Hydroxide (caustic soda) (gals)		660		204		1
1662	Potassium Hydroxide (gals)		12		1		3
1664	Calcium Hydroxide (caustic lime)				5		
1665	Potassium Hydroxide (lbs)					51	
1909	Caustic wastes with NaOH, Na3PO4, Dodecylbenzene, etc.						335
1913	Decontaminating Agent, DS-2 (pH > = 12.5) (gals)		162		452		654
1914	Decontaminating Agent, DS-2 (pH > = 12.5) (lbs)					695	

Table 10. Toxic hazardous wastes generated at Fort Riley.

CLIN	DESCRIPTION	1989		1990		1991	
		LBS	GALS	LBS	GALS	LBS	GALS
2000	EP Toxic, Misc in containers < 1 gal					195	1
2001	EP Toxic (Toxicity Characteristic), Misc in containers < 7 lbs					1605	
2004	EP Toxic (Toxicity Characteristic), Misc (lbs)	1900		2371		2343	
2005	EP Toxic (Toxicity Characteristic), Misc (gals)		78		5		8
2006	Mercury (lbs)	55		22		2	
2007	Mercury (gals)				2	26	1
2120	Debris contaminated with (but not limited to) Mercury	88		451		1	
2134	Water, may have heavy metals, nitrating acids, etc.				150		
5600	Toxics, misc in containers < 1 gal		1	1	15		1
5601	Toxics, misc in containers < 7 lbs	53		2		95	
5604	Toxics, misc (lbs)	241		10			60
5605	Toxics, misc (gals)	5			1		16
5607	Formaldehyde				1		
5615	Mercury					15	
5621	Asbestos (STATE REGULATED)			6			

Table 11. Ignitable hazardous wastes generated at Fort Riley.

CLIN	DESCRIPTION	1989		1990		1991	
		LBS	GALS	LBS	GALS	LBS	GALS
2300	Ignitables, Misc in containers < 1 gal		8	71	86		63
2301	Ignitables, Misc in containers < 7 lbs	5		356	5	1590	
2304	Ignitables, Misc (lbs)	1		33		1666	
2305	Ignitables, Misc (gals)	21	2165		1872		1528
2306	Aerosols, Ignitables, not empty			327		87	
2310	Cleaning compound (solvents, mineral spirits)				55		56
2311	Gasoline, may be contaminated		865		1625		55
2314	Alcohol, Isopropyl (isopropanol)		10		105		31
2315	Thinners		15		59		194
2316	JP-4, may be contaminated or off-spec				857		
2331	Calcium Hypochlorite, more than 39% chlorine			521	12	166	
2332	Bleaching Powder (chlorinated lime, more than 39% chlorine)				542		
2340	Ether (ethyl ether)						2
2361	Alodine/Iridite						1
2397	Alcohol, Isopropyl (isopropanol)					2	
2412	Alcohol, Denatured					14	

Table 12. Hazardous pesticide wastes generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
3400	Pesticides, Misc in containers < 1 gal				1		
3401	Pesticides, Misc in containers < 7 lbs			4		66	
3404	Pesticides, Misc (lbs)	30				87	
3405	Pesticides, Misc (gal)		93				8
3406	Aerosols, Pesticides, not empty	14		81		204	
3411	Diazinon		9		13		47
3416	Lindane (gammabenzene hexachloride) (lbs)	32		5		11	
3417	Lindane (gammabenzene hexachloride) (gals)				4	1	3
3420	Warfarin (3-(alpha-acetonylbenzyl)-4-hydroxycoumarin)	55		40		3	
3426	Baygon (orhto-iso-propoxyphenyl)					34	
3433	Sodium Arsenite (sodium metaarsenite)					1	

Table 13. Hazardous photography wastes generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
3700	Photography wastes, misc, in containers < 1 gal						1
3705	Photography wastes, misc, (gals)				65		
3707	Developers		3				
3709	Toners						9

Table 14. Other hazardous wastes generated at Fort Riley.

CLIN	DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
600	Compressed Gas Cylinders, Misc.					48	
1201	Containers, >1 gal, with more than 1 inch of hazardous wastes	19,080		8353			
4201	Reactives, Misc in containers < 7 lb					1	
5500	Spill Residues, misc and/or debris, RCRA or state regulated					543	
5900	Detector Kit, Chemical Agent (M256)					7	
5901	Decon Kit including (but not limited to) M258, M258A1					72	

Table 15. Other controlled wastes generated at Fort Riley.

		1989		1990		1991	
CLIN	DESCRIPTION	LBS	GALS	LBS	GALS	LBS	GALS
6000	NON-RCRA wastes, misc in containers < 1 gal		8	48	86		35
6001	NON-RCRA wastes, misc in containers < 7 lbs	1	3	268		385	
6004	NON-RCRA wastes, misc (lbs)	1792		404		1388	
6005	NON-RCRA wastes, misc (gals)		385		4273		3471
6006	Aerosols					12	
6007	Asbestos and asbestos contaminated wastes	134		6		2	
6011	Containers, 1 gal or larger, with more then 1 inch of non-hazardous wastes			2383			
6013	Brake Fluid (polypropylene glycol, monobutyl ethers)						111
6014	Grease	904		2443	35	131	
6015	Hydraulic fluid		255		301		6
6026	Oil, Lube		120		912		31
6049	Decon Agent, STB, < 39% chlorine	118		240		2080	
6055	Decontaminating Agent, DS-2 (pH < 12.5)				1		
6093	Calcium Hypochlorite, < 39% chlorine			93			
6098	Petroleum Lubricants (used) with diesel and burner fuels, water, dirt, etc.				125		10
6100	Oil, mixed engine, hydraulic, brake, diesel, and heating		110				
6102	Batteries, Magnesium					1555	
6137	Latex Paint					200	

4 Waste Minimization for Motor Pools and Vehicle Maintenance Facilities and Aviation Maintenance Facilities

The typical maintenance and repair operations conducted in a vehicle or aviation maintenance facility are oil and grease removal; engine, parts, and equipment cleaning; rust removal; and solution replacement. Table 16 lists the operations, the corresponding materials used, and the wastes generated at typical MPVM and AMF. Most of the wastes generated at MPVM are parts cleaning solutions and miscellaneous detergent solutions, oil and grease from engine cleaning, spent automotive fluids, and lead-acid batteries. AMF generate most of the above wastes (except automotive fluids and lead-acid batteries) plus nickel-cadmium batteries. Paint removal and painting operations may also occur at both MPVM and AMF. The minimization of painting wastes is discussed in Chapter 7.

Some of the equipment used, primarily in parts cleaning operations, are solvent sinks, hot tanks, and jet spray washers. Proper operation of this equipment minimizes material use and waste generation. The solvent in the sinks is recirculated continuously from a tank to the parts wash tray. The solvent (e.g., PD680-II) is replaced periodically. Hot tanks contain aqueous detergent or caustic solutions for immersion cleaning. These tanks are equipped with air or mechanical agitation devices and electrical heating devices to heat the solution to 356 °F. The jet spray washers consist of nozzles that emit rotating water jets to clean parts immersed in an aqueous wash solution. The contaminated liquid and sludge from the hot tanks and jet sprays are removed periodically.

Most of the minimization options discussed below have been obtained from *Waste Audit Study -Automotive Repairs*,[28] and other references.[29]

---

[28] W.M. Toy, *Waste Audit Study - Automotive Repairs* (Prepared for the California Department of Health Services, Sacramento, CA, 1987).

[29] *Hazardous Waste Reduction Checklist - Automotive Repair Shops* (California Department of Health Services, Toxic Substances Control Division, 1988); *Hazardous Waste Reduction Assessment Handbook - Automotive Repair Shops* (California Department of Health Services, Toxic Substances Control Division, 1988).

Source Reduction

All Wastes - Better Operating Practices

Better housekeeping practices are necessary to minimize the quantity and toxicity of wastes or emissions generated. Some of the methods include closing the lids of containers (e.g., solvent sinks) containing volatile substances (e.g., Stoddard solvent), conveniently locating cleaning equipment near service bays, increasing employee awareness of proper waste handling and disposal procedures, labeling hazardous waste containers properly, segregating wastes in separate containers, and separating trash/solids before waste collection for recycling or treatment.[30] Draining wastes to a sewer is not a good practice and may be illegal in many states. Inadvertent losses (spills) also can be minimized by using good housekeeping practices.

All Wastes - Better Operating Practices - Segregation

Segregation of waste streams is a very good practice that minimizes hazardous waste generation and increases the recyclability of wastes. It is extremely important not to mix solvents and oils. Mixing results in a liquid with very little recycle value and increases the costs of disposal.[31] Minimizing the quantity of contaminants in solvents improves the purity of reclaimed solvent (in onsite recycling) and increases its market value (in offsite recycling). Used oils, after being drained from engines can become contaminated with parts cleaning solvent, carburetor cleaner, fuels, rags, water, trash, and other materials.[32] These contaminants may make the used oil a hazardous waste due to ignitability, corrosivity, or toxicity, thereby reducing the possibility of energy recovery by burning it in boilers or reducing its market value (for offsite reclamation).

All Wastes - Better Operating Practices - Periodic Maintenance and Cleanup of Equipment

All the equipment, including solvent sinks, hot tanks, and spray washers, must be properly maintained. The tank bottoms must be cleaned frequently to reduce sludge accumulation and contamination of replacement solutions.

---

30 W.M. Toy, pp 27-28.

31 R.H. Salvesan Associates, *Used Oil and Solvent Recycling Guide*, Final Report (Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1985).

32 L.C. Chicoine, G.L. Gerdes, and B.A. Donahue, *Reuse of Waste Oil at Army Installations*, Technical Report N-135/ADA123097 (USACERL, September, 1982).

Solvent (PD680-I) - Material Substitution - PD680-II

Petroleum distillate Type I (PD680-I) is a flammable substance with a flash point of about 105 °F, which is below the USEPA's flammability hazard limit of 140 °F. It should be substituted with petroleum distillate Type II (PD680-II), which has a flash point of 140 °F or above. Changes should be made in the local and centralized procurement processes to prevent users from obtaining PD680-I. When ordering solvent, the user must specify that substitution is not acceptable.

Solvent (PD680-II) - Better Operating Practices

A parts cleaning solvent, such as PD680-II, must not be used to clean floors or hands. It is expensive and must be dedicated to the intended purpose of parts cleaning only. Immersion and removal of parts from the solvent sinks must be done slowly to minimize splashes and rapid evaporation of solvent.

Solvent (PD680-II) - Better Operating Practices - Emissions Minimization

Reducing air emissions is probably the most significant good housekeeping practice in terms of reducing hazardous wastes released to the environment. Using covers on solvent sinks (or cold cleaning tanks) can result in a 24 to 50 percent reduction in solvent losses.[33] Several standard methods are available for minimizing emissions from immersion cleaning, wipe cleaning, and spray cleaning operations.[34]

Solvent (PD680-II) - Process Change

If dip tanks or dunk buckets full of solvent are used for parts cleaning, the process should be modified. Solvent sinks clean parts more effectively and are easy to use. Also, using solvent sinks rather than dip tanks or buckets will reduce spillage and evaporation of the solvent. Some equipment leasing services lease solvent sinks. The equipment, raw materials, maintenance, and waste removal are part of the contract and are included in the service price. Testing of solvents (discussed in the next section) before changing should be included in the contract.

---

[33] ICF Associates, Inc., *Guide to Solvent Waste Reduction Alternatives: Final Report* (Prepared for the California Department of Health Services, October 1986), pp 4-11 through 4-13.

[34] ASTM Standard D3640-80, "Standard Guidelines for Emission Control in Solvent Metal-Cleaning Systems," *Annual Book of American Society of Testing and Materials Standards*, Vol 15.05 (American Society of Testing and Materials [ASTM], 1988).

If a leasing service is not desirable economically, the installation can purchase parts washing sinks and a solvent still and recycle the solvent onsite (as discussed in the subsequent section *Recycling Onsite / Offsite).*

Solvent (PD680-II) - Process Change - Testing

Solvents are normally replaced periodically, based on the operator's perception of "dirtiness". Simple tests to estimate the "solvation power" of the spent solvent can be used to extend the life of the solvent before disposal. The physicochemical tests most useful for used solvent testing are absorbance, specific gravity, viscosity, and electrical conductivity.[35] Testing instruments (optical probe colorimeter, electronic specific gravity meter, Ostwald viscometer, and electrical conductivity meter) are commercially available. By obtaining a measure of these properties, the usefulness of the solvent can be determined. Using solvent testing will reduce raw material and waste disposal costs and minimize the wastes generated.

Solvent (PD680-II) - Process Change - Solvent Sinks (Equipment) Modifications

Solvent losses can be minimized by adding drip trays and lids to existing solvent sinks. About 25 to 40 percent of the solvent is lost because of spillage and about 20 percent because of evaporation.[36] Racks or baskets may be designed and fitted to the solvent sinks to drain parts after cleaning. Minimizing solvent losses results in cost savings for the raw material and waste handling/disposal.

Carburetor Cleaner - Product Substitution

Carburetor cleaners typically contain methylene chloride (< 47 percent), 1,1,1-trichloroethane (< 5 percent), cresylic acid (< 27 percent), and wetting agents. The automobile industry has reformulated them to exclude the use of 1,1,1-trichloroethane.[37] Substitute cleaners should be used.

Used Oil - Better Operating Practices - Selective Segregation

Segregation of used oils and related products is not a source reduction alternative in the strictest sense of the term, yet selective segregation of used oil products may

35 B.A. Donahue, et al., *Used Solvent Testing and Reclamation, Volume I: Cold-Cleaning Solvents*, Technical Report N-89/03/ADA204731, Vol I (USACERL, December 1988).

36 W.M. Toy, pp A-1 - A-23.

37 W.M. Toy, p 20.

ultimately reduce the large volumes of hazardous wastes[38] that could be produced by mixing used oils with radiator drainings (containing oxylates, phenols, ketones, and acids) and used solvents. Product segregation is initially cost-intensive, but many factors favor selective segregation of used oils. These factors include but are not limited to: the increasing costs of hazardous waste disposal, particularly for mixed waste disposal; the fact that the British thermal unit (Btu) value of used oil for burning as a fuel is lowered by the presence of solvents; and under USEPA regulations, hazardous wastes cannot be burned except in boilers with air pollution controls and secondary burners. These factors effectively prohibit blending used oil with boiler fuel if the used oil is listed as a hazardous waste.

Caustic Wastes - Product Substitution

Caustic cleaning compounds are used in hot tanks and jet spray washers. Substitution of detergent compounds minimizes the amount of hazardous (corrosive) wastes produced. Caustic compounds are necessary for cleaning engines made of iron or iron alloys. With the rapid change to manufacturing engine blocks of aluminum, the use of detergent solutions for cleaning also is increasing.

Caustic Wastes - Process Change - Hot Tank (Equipment) Modifications

A major waste from hot tank operations is the tank bottom sludge containing heavy metals, oil, grease, etc. A typical practice is to dislodge the sludge from the bottom of the tank and dump it into a sump. Installing a collection tray with an overflow to the sump will allow for proper capture and disposal of the sludge. Hot tanks also must be equipped with drip trays and pans for collecting solution that drips off the parts after cleaning. The solution in the trays or pans must then be emptied back into the hot tank.

Aqueous or Caustic Wastes - Process Change - Dry Ovens

Hot tanks or spray washers typically are used for engines/parts washing. If the parts are small enough, ovens could be used to burn off the grease, oil, and particles. The dry ash can then be removed from the parts using shot blasters (preferably with plastic beads) and disposed of in a landfill. The ash must be tested for toxicity before assigning a disposal method. Testing the oven stack emissions for air pollutants may be required; however, using a dry oven will eliminate hazardous (corrosive and toxic) wastes that contain caustics, heavy metals, and oily dirt.

---

[38] D.W. Brinkman, M.L. Whisman, and C.J. Thompson, *Management of Used Lubricating Oil at Department of Defense Installations: A Guide*, NIPER B06711-2, (National Institute for Petroleum and Energy Research, 1986), p 26.

Aqueous Wastes - Process Change - Two-Stage Cleaning in Jet Spray Operations

Most of the parts covered with oil, grease, and heavy dirt residues are cleaned using jet spray operations. If many parts need to be cleaned, a two-stage cleaning operation might provide cleaner parts in a shorter time. Two washers can be connected in series with the first removing most of the heavier residue and the second providing the final rinse. The cleaning solution from the second tank is transferred to the first tank (countercurrent processing.)

Antifreeze Solution - Product Substitution

Biological treatment of the ethylene glycol waste stream is difficult and the chlorination processes (commonly used in a waste treatment plant) generate other toxic chlorinated hydrocarbons. Substituting propylene glycol for ethylene glycol in antifreeze formulas will reduce the toxicity of the waste stream. Propylene glycol is a nontoxic compound commonly used as a food additive.[39]

Antifreeze Solution - Process Change - Testing

Testing the antifreeze solution before draining and disposal can help minimize the amount of wastes generated. Standard methodologies available for testing engine coolants in cars and light trucks[40] may be adapted for other types of vehicles. Electrochemical tests based on the measurement of galvanic currents have proven useful for measuring the levels of corrosion inhibitors and corrosivity of the antifreeze solution in a radiator (or any other heat transfer device).[41] Such test methods allow continuous monitoring of the solution to determine the exact time of change rather than change on a periodic basis, such as 6 months, or when the mechanic thinks it is dirty.

---

39 F.E. Mark and W. Jetter, "Propylene Glycol, A New Base Fluid for Automotive Coolants," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (American Society of Testing and Materials [ASTM], 1986), pp 61-77.

40 ASTM Standard D2847-85, "Standard Practice for Testing Engine Coolants in Car and Light Truck Service," *Annual Book of American Society of Testing and Materials Standards*, Vol 15.05 (ASTM, 1988).

41 R.L. Chance, M.S. Walker, and L.C. Rowe, "Evaluation of Engine Coolants by Electrochemical Methods," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (ASTM, 1986), pp 99-102; C. Fiaud, et al., "Testing of Engine Coolant Inhibitors by an Electrochemical Method in the Laboratory and in Vehicles," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (ASTM, 1986), pp 162-175.

Antifreeze Solution - Process Change - Extend Life

A Military Specification, MIL-A-53009,[42] developed by the U.S. Army Research and Development Center, Fort Belvoir, VA, allows the use of antifreeze (MIL-A-46153)[43] whose inhibitor system has reached a marginal condition.[44] The military additive can extend the life of the antifreeze by more than 1 year. It was originally developed for use if new antifreeze was in short supply. During 1987 and 1988, ethylene glycol was in short supply because of the unavailability of ethylene (base stock) and the retail price doubled. In addition to environmental incentives, economic incentives to minimize the quantities of ethylene glycol wastes generated also exist.

Brake Shoes (Asbestos Waste) - Better Operating Practices

Asbestos dust, released when replacing brake shoes, is an inhalation hazard. Friable (crushable under hand pressure) asbestos must be carefully collected and handled as a hazardous waste. Some equipment leasing companies may also provide asbestos collection services.

Recycling Onsite/Offsite

Solvent (PD680-II) - Onsite Recycling - Distillation

If large quantities of solvents are used (i.e., over 4000 gal/yr) they can be recycled onsite using distillation units. These units offer a quick investment payback (i.e., less than 3 years).[45] In the distillation process, the solvent is boiled and the vapors are condensed and collected in a separate container. Substances with a higher boiling point than the solvent (e.g., oils, metal residues, etc.) remain in the bottom of the still. A smaller amount of contaminants will result in a higher purity for the reclaimed solvent. Therefore, it is very important to segregate solvent wastes from oils and other contaminants in the service bays. Table 17 lists some suppliers of solvent distillation equipment and approximate prices. Table 18 lists suppliers of solvent sinks and their

---

42 Military Specification MIL-A-53009, *Additive, Antifreeze Extender, Liquid Cooling System* (Department of Defense [DOD], 6 August 1982).

43 Military Specification MIL-A-46153, *Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package* (DOD, 31 July 1979).

44 J.H. Conley and R.G. Jamison, "Additive Package for Used Antifreeze," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, Ed., ASTM STP 887 (ASTM, 1986), pp 78-85.

45 R.H. Salvesan Associates, pp 35-36.

prices. Detailed comparisons of the economics of distillation and solvent management options discussed in this chapter are available elsewhere.[46]

Solvent (PD680-II) - Offsite Recycling - Contract/Leased Recycling

Solvent sinks for parts cleaning can be owned or leased. In a lease arrangement, the contractor (e.g., Safety-Kleen [SK]) replaces fresh solvent periodically (specified in the contract) and takes the spent solvent for recycling. Wastes can thus be better contained and the solvent recycled rather than disposed of. Contract recycling has been accepted as a good practice by the automobile industry.[47]

Carburetor Cleaner - Offsite Recycling - Contract/Leased Recycling

Some companies distill spent carburetor cleaners and return the cleaner to the user. Equipment similar to solvent sinks are available for lease or purchase. The contract fees include the cost of periodic pickup and disposal of sink bottoms.

Used Oil - Onsite Recycling - Gravity Separation/Blending

A state-of-the-art RACOR™ oil-to-fuel blending system that will help avoid the problem of disposing of used oils has been developed. The RACOR system is typically used in conjunction with a fuel reservoir or tank. The system blends waste diesel crankcase oil with diesel fuel. It also filters/recycles and transfers diesel fuel from the fuel holding tank. The system comes with a waste holding tank and oil injection system. Used oil from the systems holding tank is blended into diesel fuel (not to exceed 5 percent) and cycled through a three-stage filter to remove water and solid contaminants, resulting in a fuel that is 99.5 percent free of emulsified water and solid particulates. Use of a closed-loop system such as the RACOR system may satisfy all technical requirements and military specifications for oil/fuel blends[48] and should be tested.

Used Oil - Offsite Recycling - Closed-Loop Contract

A closed-loop re-refining contract stipulates that the re-refiner agrees to process the used oil furnished by the generator, returning it to original quality for a contracted

---

46 B.A. Donahue and M.B. Carmer, *Solvent "Cradle-To-Grave" Management Guidelines for Use at Army Installations*, Technical Report N-168/ADA137063 (USACERL, December 1983); *Economic Analysis of Solvent Management Options*, Technical Note 86-1 (Department of the Army, May 1986).

47 W.M. Toy, pp 29-30.

48 D.W. Brinkman, W.F. Marshall, and M.L. Whisman, *Waste Minimization Through Enhanced Waste Oil Management*, NIPER B06803-1 (National Institute for Petroleum and Energy Research, 1987); T.C. Bowen, Personal Communication, U.S. Army, Belvoir R&D Center, Materials, Fuels, and Lubricants Laboratory, Fort Belvoir, VA, 1987.

price per gallon. The re-refiner does not take ownership of the used oil but merely assumes custody of the oil until it is returned to the generator.

Among the possible disadvantages of a closed-loop contract is that installations may wish to offer used oil, solvents, and synthetic lubricants as a package. Of more immediate and important concern, is that before re-refined oil can be used in government vehicles and engines, it requires approval for the Qualified Products List. Approval is a costly procedure but ensures that the product meets specifications. With estimates of $50,000 for an engine sequence test (1982 dollars) to qualify used oil to meet Army requirements,[49] many re-refiners are reluctant to enter into a contractual agreement unless the cost of such tests can be included in the closed-loop contract.[50] More recent studies have placed the cost of such a qualification procedure at $75,000.[51]

Used Oil - Offsite Recycling - Sale to Recyclers

Sale of used lubricating oils may be the most economical answer for an installation. Although burning and closed-loop recycling agreements offer increased economic rewards, constraints may limit the options available to an installation and make selling used oil the only feasible alternative. The cost of selling or disposing of used oil includes sampling and testing the oil, storage before the sale, 55-gal drums for sale/disposal, inventorying expenses, advertising for bid solicitations, bid evaluation, bid letting, and accounting. Draft USEPA regulations, when finalized, could increase the workload of sales personnel slightly by requiring the selling installation (or DRMO/DRMS) to notify the USEPA of the intent to market used lubricating oil and obtain an identification number. Certified analyses on each batch of used oil will also be required, and if the oil is classified as a hazardous waste, it must be manifested and transported by a licensed hazardous waste hauler and may be distributed only to an industrial user.

Antifreeze Solutions - Onsite Recycling

In addition to reducing the quantity of waste produced, there are major economic incentives for recycling and reusing antifreeze solutions. New antifreeze is expensive, and the cost to dispose of used antifreeze can be even higher than the cost to purchase new antifreeze. A simple recycling method is available that uses mechanical filtration to remove large particles before the solution is pumped into a large tank. An antifreeze extender is added to the tank based on the measured pH to neutralize the

---

49 Mil-L-46152, *Lubricating Oil, Internal Combustion Engine, Administrative Service, Metric* (DOD, 1 August 1988).

50 L.C. Chicoine, G.L. Gerdes, and B.A. Donahue, pp 16-19.

51 D.W. Brinkman, M.L. Whisman, and C.J. Thompson, p S-3.

acidic byproducts in the used antifreeze. A small amount of new antifreeze may also need to be added to reduce the freezing point to -34 °F. The whole recycling system is available as a skid-mounted, 100-gal batch unit.[52] Using this system is expected to reduce new antifreeze purchases by 80 percent or more. See the May 1994 TARDEC Technical Report No. 13614 and 13628 for updated guidance on antifreeze recycling.

Lead-Acid Batteries - Offsite Recycling

Because of their weight, lead-acid batteries are the largest quantity of waste generated from vehicle maintenance facilities. Battery recyclers may pay up to $1.00 to $1.50 per battery. Previous HAZMIN assesments reported prices of $0.20 to $0.40 per pound, wet or dry. This research resulted in a cost of $0.04 to $0.065 per pound, wet or dry. Apparently prices fluctuate greatly depending on the market; check with recyclers for current costs. The batteries are rebuilt or processed to recover lead. Approximately 20 percent of the batteries can be rebuilt. Several processors and smelters of lead-acid batteries are located throughout the US. Installation logistics personnel can transport unserviceable lead-acid batteries to a recycling facility if one is located nearby. A bill of lading is required if more than 10 batteries are transported at any time. Use of a registered hazardous waste hauler is not required and the waste does not have to be manifested; however, cracked or broken batteries must be transported as hazardous waste by registered haulers.

Aqueous or Caustic Wastes - Equipment Leasing

Hot tanks and spray washers are also available from equipment leasing companies. The leasing service fee is site-specific and usually includes the raw materials, equipment maintenance, and waste disposal costs.

Dirty Rags/Uniforms - Onsite/Offsite Recycling - Laundry Service

Rags used to wipe up spills or clean off grease must not be disposed of as trash in a solid waste container. They should be collected and sent with dirty uniforms to a laundry for cleaning.

52 *GLYCLEAN - Anti-freeze Recycling System*, brochure (FPPF Chemical Co., Inc., 117 W. Tupper St., Buffalo, NY 14201, 1988).

Treatment

Used Oil - Onsite Pretreatment - Filtration

A number of filtration devices are available for removing solids from used oil. Simple screen filters should be used when draining oil into containers to prevent entry of large objects (e.g., rags, cans, trash, etc.). Other filter media ranging from sand to fibrous material are available in filtration units for removing solids and even water.

Used Oil - Onsite Pretreatment - Gravity Separation

Gravity separation units are composed of a series of tanks used to contain oil and allow for gradual sedimentation of solids and water because of gravitational force and buoyancy. These units usually include skimmers and pumps to remove the water and solids. Some of the units use heat to enhance separation. Gravity separators are effective on used oils that do not contain emulsions and when a sufficient residence time can be provided for settling to occur.[53]

Used Oil - Onsite Treatment - Blending/Burning

Used oil exceeding any of the specification levels for toxic metals, flash point, or total halogen content is termed "off specification used oil" and is subject to regulatory controls. Furthermore, an installation without an industrially classified boiler and whose used oil has hazardous characteristics (heavy metals, halogens, toxics) must blend the oil to meet burning specifications. Regulations regarding used oil for burning can be found in a DOD Memorandum.[54]

Classification as an industrial boiler requires that energy from the boiler be used in manufacturing operations. The manufacture of steam or heat does not satisfy this criteria.[55] The amount of used oil to be blended with the fuel is not likely to have short-term impacts on the combustion efficiency of a boiler, but long-term use will likely present a problem in repeated clogging of pipes and nozzles, accelerated corrosion of pipes and tanks, and a reduction of heat transfer efficiency.[56] Current Navy regulations limit the amount of used oil in fuel oil blends to 1 percent.[57]

---

[53] R.H. Salvesan Associates, pp 54-57.

[54] DOD Memorandum for Deputy of Environment, Safety and Occupational Health, OASA (I&L); Deputy Director for Environment, OASN (S&L); Deputy for Environment and Safety and Occupational Health (SAF/MIQ); Director, Defense Logistics Agency (DLA-S); 28 January 1986, Subject: Regulation of Used Oil for Burning.

[55] D.W. Brinkman, M.L. Whisman, and C.J. Thompson, p 34.

[56] L.C. Chicoine, G.L. Gerdes, and B.A. Donahue, pp 33-43.

[57] C.W. Anderson, *Cost-Effectiveness Analysis of Lubricant Reclamation by the Navy,* Technical Note 1481 (Naval Civil Engineering Research Laboratory [NCEL], Port Hueneme, CA, 1977).

Mixtures up to 5 percent oil, however, appear to have no appreciable impact on the Btu value of the fuel oil mixture and result in only minor additional maintenance costs, although long-term impacts of blending/mixing on operating parameters of boilers are unknown.

Before blending and burning, used oils must be filtered to remove any large impurities. Other important characteristics of used oils as a boiler fuel are API gravity and viscosity. Viscosity will impact the flow rate of the fuel and the spray pattern from the nozzle as the fuel is introduced to the boiler. The API gravity of an oil is a function of the specific gravity and is related to the heat of the burning oil. Firing temperatures for a given viscosity and discussions of the relationships between specific gravity, API gravity, and heating value can be found in literature.[58]

Aqueous Wastes - Onsite Pretreatment - Filtration

Installing filters on aqueous waste streams to collect grit and heavy residue increases the life of the wash solution. In one case,[59] providing a pump-around loop through a 25-micron filter bag (on a slipstream from jet spray washer) extended the solution life by 2 weeks, thus minimizing the quantity requiring subsequent treatment or disposal.

Aqueous Wastes - Onsite Treatment - Evaporation

Aqueous wastes consist primarily of water with various amounts of contaminants. Evaporating the water minimizes the amount of waste requiring disposal. In an evaporation device, the water is heated away (using an electric or natural gas heating device) leaving behind a semisolid or solid residue requiring disposal. Oil, if present in the waste, could inhibit boiling. Solid residue accumulated on the inner surface of the evaporator could inhibit heat transfer and, therefore, it may have to be cleaned frequently.

Aqueous Wastes - Onsite Treatment - Waste Treatment

Onsite batch treatment devices that neutralize and precipitate heavy metals from aqueous wastes are available.[60] A pretreatment system is included to separate oil and grease. Sulfuric acid is added to reduce the pH to between 2 and 3 to reduce any hexavalent chrome to a trivalent state. Adding sulfites leads to precipitation of trivalent chrome. Sodium hydroxide is then added to raise the pH and precipitate the

---

58 T.T. Fu and R.S. Chapler, *Utilization of Navy-Generated Waste Oils as Boiler Fuel - Economic Analysis and Laboratory Tests*, Technical Note N-1570 (U.S. Navy Construction Battalion Center, 1980), pp 14-44.

59 W.M. Toy, p 27.

60 W.M. Toy, p 25-27.

remaining metallic species. The precipitates settle to the bottom as a sludge and the water decanted from the top may be reused in cleaning processes. A filter press is included to reduce the water content of the sludge produced, thus also minimizing the volume to be disposed of.

Carburetor Cleaner - Offsite Treatment

Some solvent recyclers (e.g., SK, Safe-Way Chemical) send spent carburetor cleaners to another company (e.g., Solvent Services) for treatment. This treatment process produces a lacquer wash from the spent carburetor cleaner.[61] Lacquer wash can be recycled and used in paint stripping processes.

Antifreeze Solution - Offsite Treatment

If large quantities of spent antifreeze solutions are generated at vehicle maintenance operations, the solutions can be treated at an approved treatment facility for recovery of ethylene glycol that may be used as waste fuel.

Lead-Acid Battery Electrolyte - Treatment

Lead-acid batteries should not be drained. These batteries are not a hazardous waste if they are sold to a recycler. Draining the batteries creates two types of wastes: lead dross, and spent sulfuric acid contaminated with lead. In 1992, the Fort Riley DRMO stated they would begin accepting lead-acid batteries wet. A conforming storage facility is required with appropriate ventilation, heating, and spill containment.

NICAD Battery Electrolyte - Treatment

NICAD battery cells contain a caustic potassium hydroxide solution (31 percent by weight). This electrolyte is corrosive. The electrolyte also contains cadmium and cadmium salts that are listed by the USEPA as hazardous wastes. The electrolyte must be tested for cadmium and neutralized before disposal.

---

[61] W.M. Toy, pp 31-32.

Table 16. Typical MPVM and AMF operations with materials used and wastes generated.*

Process/ operation	Materials used	Ingredients	Wastes generated
Oil and grease removal	degreasers - (gunk), carburetor cleaners, engine cleaners, varsol, solvents, acids/alkalis	petroleum distillates, aromatic hydrocarbons, mineral spirits	ignitable wastes, spent solvents, combustible solids, waste acid/alkaline solutions
Engine, parts, and equipment cleaning	degreasers - (gunk), carburetor cleaners, engine cleaners, solvents, acids/alkalis cleaning fluids	petroleum distillates, aromatic hydrocarbons, mineral spirits, benzene, toluene, petroleum naptha	ignitable wastes, spent solvents, combustible solids, waste acid/alkaline solutions
Rust removal	naval jelly, strong acids	phosphoric acid, hydrochloric acid, hydrofluoric acid, sodium hydroxide	waste acids, waste alkalis
Solution replacement	antifreeze solution, petroleum oil	ethylene glycol, petroleum distillates	hazardous liquid, combustible liquid
Lead-acid batteries; recharging, repair, draining	automobile, truck, tracked vehicle, and other equipment batteries	lead dross, less than 3 percent free acids	used lead-acid batteries, strong acid
NICAD batteries; repair, draining	helicopter and airplane batteries	Battery cells containing KOH	used NICAD battery cells, strong alkali

* Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986).

Table 17. Solvent recovery equipment.

Supplier	Model	Capacity	Cost
Finish Thomson*	LS Jr	3-5 gal/day	$4,860
Dove Equipment Co.	LS 15-IID+vacuum	1.9 gal/hr	$14,380
1110 N. Main Street			
East Peoria, IL 61611			
(309) 694-6228			
Progressive Recovery Inc.*	SC25W+cont.flow	2-3 gal/hr	$18,200
700 Industrial Drive	SC100	7.5 gal/hr	$16,500
Dupo, IL 62239			
(618) 286-5009			
Solvent Recovery Systems**	SRS-15	1.25 gal/hr	$9,640
14335 W. Interdrive "A"	SRS-25	3 gal/hr	$15,525
Houston, Texas 77032	SRS-100	6 gal/hr	$18,664
(713) 449-8871			
Solvent Kleene	PF20	1.5-2 gal/hr	$11,950
131.5 Lynnfield Street			
Peabody, Mass 01960			
PBR Industries**	AV60/GV60	1.9 gal/hr	$14,400
400 Farmingdale Road	AV100/GV100	3.125 gal/hr	$38,888
West Babaylon, NY 11704			
(516) 422-0057			

* GSA contract holder.
** GSA contract applied for.

Table 18. Parts washing sinks.

Manufacturer	Size	Price
Amax 300 Heyburn Building Louisville, KY 40202 800-662-0023	5 gallon 10 gallon 15 gallon	$397 $545 $647
Norton 290 Possum Park Rd. Newark, DE 19711 (302) 731-8220	5 gallon 10 gallon	$384 $446
B-Clean* N59 E14508 Bobolink Ave. Menomonee Falls, WI 53051 (414) 252-3230	5 gallon (portable) 15 gallon	$529 $332

* GSA contract holder.

5 Waste Minimization for Industrial Maintenance, Small Arms Shops

Most of the hazardous wastes generated from IMSS operations can be categorized as corrosive wastes (acids and alkalis), spent solvents, paint stripping wastes, and wastes containing toxic metals. The operations that generate these wastes include equipment and vehicle repair, metal cleaning, surface preparation, and metal finishing. A summary of processes, wastes generated, and DOT classifications are listed in Table 19. The minimization options for vehicle maintenance repair wastes are discussed in Chapter 4.

Chlorinated or nonchlorinated solvents are commonly used to clean or degrease parts before repair, rebuilding, or finishing. Nonchlorinated solvents (e.g., petroleum distillates) are normally used in cold cleaning operations using solvent sinks or dip tanks. Chlorinated solvents such as TCE, 1,1,1-trichloroethane, methylene chloride (MC), and perchloroethane, are used in vapor degreasers, where condensing solvent vapors remove the grease, oil, or wax from the dirty parts. 1,1,1-trichloroethane is the safest of these four solvents and is the most commonly used. IMSS operations at Fort Riley primarily use petroleum distillates in solvent sinks. Minimization options for solvent use were discussed in Chapter 4.

Cleaning with caustic compounds or detergents also occurs at IMSS operations. Cleaning is usually followed by surface preparation such as painting or scale stripping. Sand, glass, or shot blasting are common methods of removing paint or scale. In some cases, paint stripping is accomplished with solvent (MC) or caustic strippers.

Metal finishing operations, such as surface finishing of small arms, and metalworking, such as cutting and threading are also common at IMSS. A small arms shop conducts weapons rebuilding on many types of small arms. Chemicals such as chromic acid, phosphoric acid, etc., are used. Manganese phosphate coatings are the most common surface finishing treatments used on small arms components. The phosphate coating is dull black and provides wear resistance to the cast iron/steel surfaces. The first step in the process is to clean the parts. The methods include vapor degreasing or alkali cleaning, blasting with sand/walnut shells, self-emulsified solvent treatment, and phosphoric acid-solvent-detergent cleaning. The parts are then rinsed in water, coated with phosphate, and rinsed in water again immediately after the phosphate coating. The next step is to use a hot oil conditioning rinse and then dry the coated and rinsed surfaces. Any supplementary coatings are then applied.[62] The typical coating time is 15 to 40 minutes. The phosphate immersion coating bath is maintained between 200 and 210 °F. The phosphate tank and heating elements are usually made of acid-resistant material. Some of the equipment used in the immersion coating process include conveying equipment, if necessary; work-supporting equipment such as hooks, racks, baskets, and tumbling barrels; tanks associated with water and heat (steam or electricity); a drain to the sewer line; ventilation equipment; and drying equipment such as ovens, air heaters, fans, and compressors.[63] The operator of the small arms shop must account for all materials used in the process. The potential for severe environmental hazards exists in the operation of a small arms shop.

The metalworking operations in IMSS use petroleum and synthetic oils and small quantities of solvents in cleaning, cutting, and threading metallic pipes and other surfaces. Used oil and waste solvents are commonly generated. Painting vehicles, equipment, and parts is also conducted by IMSS. The minimization options for painting and surface coating are discussed in Chapter 6.

The three major categories of processes relevant to Fort Riley, considered for discussion in this chapter are alkaline cleaning, dry media blasting, and cutting and threading.

Treatment - Alkaline Cleaning - Onsite Treatment of Caustic Wastes

Cleaning of metal substrate using alkaline cleaners generates a corrosive waste that must be neutralized. In addition to neutralization, removing grease and heavy metals may also be necessary. Batch treatment units are commercially available. A precipitation/neutralization system can also be designed for onsite use. Sludge collected on the bottom of the treatment tank must be tested for hazardous characteristics and disposed of properly.

Source Reduction - Dry Media Blasting

Dry Wastes - Product Substitution - Plastic Media Blasting

Plastic media blasting (PMB) is a relatively new method to remove paint and rust from a variety of metallic and alloy substrates such as aluminum, steel, titanium, copper,

---

62 A. Douty and E.A. Stockbower, "Surface Protection and Finishing Treatments - A. Phosphate Coating Processes," revised by W.C. Jones, in *Electroplating Engineering Handbook*, Fourth Edition, L.J. Durney, Ed. (Van Nostrand Reinhold Co., 1984), pp 366-390.

63 A. Douty and E.A. Stockbower.

and zinc. It is a good substitute for organic chemical stripping (using mixtures of MC and other toxic compounds) and abrasive blasting with sand, glass beads, or agricultural media (walnut shells, rice hulls, corn cobs, etc.).

Agricultural media blasting has several drawbacks such as high explosion potential, poor paint/rust removal, high contamination, low recycle rate, and generation of large quantities of wastes. Comparatively, sand and glass beads are better for blast cleaning because of good performance and low explosion potential, however they also have a very low recycle rate. Some of the advantages of PMB are: (1) it is aggressive and requires less operating time (compared to agricultural media only); (2) the plastic maintains its size and hardness; (3) the plastic does not break up and thus can be recycled 10 to 20 times,[64] resulting in lower replacement and disposal costs; and (4) overall, the method is economically favorable.

PMB is slower than sand or glass bead blasting; however, it produces a better quality finish. Also, the amount of waste produced in PMB is greatly reduced because most of the media can be recycled many times. Because of the better finish produced, and the reduced waste generation PMB can be more cost effective than sand or glass bead blasting.[65]

Some suppliers of plastic media are Aerolyte Systems, 1657 Rollins Rd., Burlingame, CA 94010, (415) 570-6000; E.I. du Pont de Nemours & Co., Inc., Fabricated Products Dept., Wilmington, DE 19898, (800) 677-4568; and U.S. Blast Cleaning Media, 328 Kennedy Drive, Putnam, CT 06260. The price of plastic media ranges from about $1.50 to $2.50 per pound.

Dry Wastes - Process Change - Plastic Media Blasting

Plastic media can often be used in existing sandblasting machines. In some cases, the blasting nozzle may need to be replaced to enable the machine to more efficiently use the plastic media. Existing abrasive blasting machines can also be replaced with more efficient plastic media blasting machines. A number of companies manufacture PMB machines. Design consultants must be retained to design for specific applications. Two types of PMB machines are available: cabinets and open blast systems. Cabinet systems are very similar to the conventional abrasive blasting machines. The most

---

[64] J. Gardner, *Dry Paint Stripping Utilizing Plastic Media: A New Solution to an Old Problem*, Technical Bulletin (Clemco Industries, 1987).

[65] C.H. Darvin and R.C. Wilmoth, *Technical, Environmental, and Economic Evaluation of Plastic Media Blasting for Paint Stripping*, EPA/600/D-87/028 (U.S. Environmental Protection Agency [USEPA], Water Engineering Research Laboratory, 1987).

commonly used cabinet has an opening that measures about 5 ft by 4 ft. Small open blast systems are portable and self-contained.

Source Reduction - Cutting and Threading

Cooling/Cutting Oils - Better Operating Practices - Material Conservation

The application of cooling/cutting oils in metalworking must be limited to the area that has to be cooled without using it in excess. Efficient applicators or directional delivery systems, if used, can reduce the amount of coolant delivered to a surface. This efficient use extends the life of oils and minimizes the amount of oil purchased and wastes generated.

Cooling/Cutting Oils - Better Operating Practices - Proper Concentration Maintenance

Performance of a coolant depends on maintaining the proper coolant to water ratio. Accurate measurements of the concentrations can be obtained by using refractometers. Also, coolant proportioning devices are available to ensure accurate mixing. Specific information on coolant maintenance can be obtained from the manufacturer.

Cooling/Cutting Oils - Better Operating Practices - Proper Storage

Water soluble oils can be stored easily. Proper storage avoids deterioration by biodegradation. The manufacturer's storage recommendations must be followed.

Cooling/Cutting Oils - Better Operating Practices - Operator Handling/Segregation

The operators of metalworking equipment must be cautioned about minimal use of coolant. They should also be trained about the hazards of mixing oils and chlorinated/nonchlorinated solvents and the associated disposal problems.

Cooling/Cutting Oils - Better Operating Practices - Chemical Purchase

When purchasing oils, screen them for undesirable hazardous components. If such information is not available in the manufacturers' Material Safety Data Sheets (MSDSs), testing may be required.

Cooling/Cutting Oils - Better Operating Practices - Metal Chips Removal

Metal chips that accumulate in a coolant must be removed frequently. They interfere with the machine's performance and serve as a site for bacterial growth. Filter screens, when placed at the entrance to the sump and at the exit from the holding trays, can prevent chips from entering the sump. The chips can then be vacuumed from the screens.

Cooling/Cutting Oils - Product Substitution

Several different brands of water soluble oils are available. Some of them contain small amounts of hazardous materials such as cresol (< 1 percent). Only those oils that do not contain hazardous materials should be purchased.

Cooling/Cutting Oils - Process Change - Equipment Modifications

Worn equipment must be repaired or replaced to optimize performance and minimize waste generation (e.g., leaks). Older models should be replaced with automated equipment.

Adding skimmers (belts or disks) to remove "tramp" petroleum oil from the cooling/cutting oils can minimize the quantities of mixed wastes produced. These skimmers must be placed near the sump containing the coolant. Timers are also available to control equipment operation and to ensure that the quantities of coolant removed with the oil are minimal.[66]

Cooling/Cutting Oils - Process Change - Process Controls

The loss of cooling/cutting oils during metalworking operations must be minimized. Adding splash guards or drip trays allows the excess oils to be collected and possibly recycled/reused. Splash guards and drip trays can also be used to contain spills in the machining areas, thus reducing the use of adsorbent material (e.g., DRY-SWEEP) and wastes generated.

Cooling/Cutting Oils - Process Change - Control Bacterial Growth

Bacterial growth in coolants can be controlled by cleaning the sump whenever the coolant is replaced, using biocides, adjusting the pH, and adequately circulating the

---

[66] *Prolonging Machine Coolant Life*, Fact Sheet (Minnesota Technical Assistance Program, Minneapolis, MN, 1988).

coolant.[67] The sump must be cleaned with steam or chemicals. In some cases, its design may have to be modified to provide sufficient access for cleaning tools.

When using biocides to control bacterial growth, it is important to realize the ultimate treatment or fate of the coolant. Bacterial test kits must be used to determine the exact amount of biocide to be added. The use of biocides can be minimized by proper pH control. Bacterial growth decreases the pH of the coolant. Measuring the pH (with a pH meter or litmus paper) and adjusting it (with caustic soda) to the manufacturer's recommended level can control bacterial growth. It is also necessary to maintain proper circulation of the coolant to ensure an oxygen enriched environment in the sump. A mixer or an agitator can be used for this.

Treatment - Cutting and Threading

Cooling/Cutting Oils - Onsite Treatment

Fine particles in oils, such as metal cuttings, can be removed in a pretreatment step by using a centrifuge. Batch centrifuges are available for small metalworking equipment. Large continuous centrifuges are available for removing particles from oils generated continuously in large volumes.

Mobile treatment services are provided by some companies to generators that produce large quantities of water soluble oils. The cost for such a service depends on the volume of oil and the concentration of contaminants.

Another physical treatment technique is ultrafiltration to remove fine particles. About 90 percent of the water fraction can be extracted and discharged directly to the sewer system.[68] The oil recovered is high quality and can be recycled.

Epsom salts (magnesium sulfate) can be used to reduce volume by precipitation and separation before disposal. However, this method is less efficient than other volume reduction techniques available.

To reuse water soluble oils, it is necessary to treat them by pasteurization followed by filtration. The biological contamination accumulated during use can thus be removed. The blend ratio of recycled oil to new oil is determined before use with a refractometer.

---

[67] *Prolonging Machine Coolant Life.*

[68] Fred C. Hart Associates, *Aerospace Waste Minimization Report* (California Department of Health Services, 1987).

Cooling/Cutting Oils - Offsite Treatment

Several offsite treatment and recovery techniques are available for cutting/cooling oils, including ultrafiltration, evaporation, and thermal destruction by incineration. The choice of a method depends on the volume of wastes and their physical/chemical state.

Table 19. Wastes genenerated at IMSS.

Process/Operation	Materials Used/Wastes Produced	HW Code
Degreasing metal surfaces/parts and other metal surface preparation	Caustic soda	D002
	Chlorinated solvents	F001
	Freon	F001
	Ignitable (flammable) degreasers	D001
	MEK	F005
	Methylene chloride	F001
	Mineral spirits solvents	D001
	Petroleum naptha	D001
	Petroleum distillates	D001
	1,1,1-trichloroethane	F001
	Trichloroethylene	F001
Metal finishing (including etching)	Spent acid solutions	D002
	Chromic solutions	D002
	Hydrochloric solutions	D002
	Nitric stripping solutions	D002
	Phosphoric solutions	D002
	Sulfuric solutions	D002
Surface preparation	Acetone	F003
	Alcohols	D001
	Caustic paint stripper	D002
	Methylene chloride stripper	F002
	Mineral spirits	D001
Metalworking	Used oils (not manifested)	None
	Spent solvents	

* Source: *Metal Manufacturing and Finishing,* Hazardous Waste Fact Sheet (Small Quantity Generators Activity Group, Minnesota Technical Assistance Program, Minneapolis, MN, 1987).

6 Waste Minimization for Paint Shops

Paints are applied to metal or other surfaces (e.g., wood) for waterproofing, flame-proofing, rustproofing, insulating, and other similar purposes. There are three different categories of paints: architectural, original equipment manufacture (OEM), and special purpose. Architectural paints are used on buildings. OEM paints are used in industries that manufacture automobiles, appliances, and furniture.[69] Special purpose paints, such as chemical agent resistant coating (CARC) are used in maintenance operations in some industries, the armed services, and highway maintenance. Forty-four percent of the special purpose coatings are used on automobiles, 18 percent in industrial maintenance, and the remaining distributed between aerosols, traffic paints, and other categories.[70]

The painting process involves paint stripping and surface preparation, application of the paint, and curing. Paint stripping (using wet or dry techniques) and surface preparation are necessary to clean the substrate and prepare it for adhesion of the paint. Paint is then applied to the surface. The method used depends on the size, shape, complexity, and number of items. After painting, the items are placed in a curing oven to remove excess solvent and make the coating uniform. Some of the common painting techniques are dip painting, flow painting, roll painting, curtain painting, spray painting, and bulk painting. Spray painting is the most commonly used technique and can be manual or automatic. Spray painting techniques (including conventional pressure/air atomized, and electrostatic centrifugal/air atomized) have transfer efficiencies that range from 30 to 95 percent. The overspray from the paint application process can be as high as 50 to 70 percent, and is in most cases collected and disposed of. The method of painting may sometimes be dictated by the type of paint formulation (e.g., water-based enamels cannot be sprayed).

Most paint formulations use solvents as carriers for binders such as pigments, powders, and adhesives. The solvent content can vary from 1 to 85 percent. Typical solvents include acetone, n-butanol, o-dichlorobenzene, diethyl ether, ethyl acetate, butanol, methyl ethyl ketone, methyl isobutyl ketone, MC, 1,1,1-trichloroethane, trichlorofluoro-methane, tetrahydrofuran, cyclohexanone, and petroleum derivatives

---

[69] ICF Associates, Inc.

[70] P.L. Layman, "Paints and Coatings: the Global Challenge," *Chemical and Engineering News* (September 30, 1985), pp 27-68.

such as naphtha, xylene, toluene, or hexane. Powder or water-based paints do not contain solvents. Solvent-based paints (e.g., acrylic lacquers) have the advantage of durability, fast drying time, low corrosivity to substrate, and high gloss finish.[71] Some of the disadvantages include emission control problems; worker exposure hazards; fire hazards; and waste management, disposal, and liability problems. The criteria used in choosing a solvent depends on the type of paint required, drying speed, the nature of the substrate, and the properties of the solvent.

In addition to the wastes from the painting process, large quantities of solvent wastes are generated during equipment cleaning. Table 20 describes the wastes generated from the painting process and lists the corresponding DOT classifications.

Source Reduction

Solvent-Based Paints - Product Substitution - Powder Coatings

Powder coating is an effective alternative to solvent-based paints. In a powder coating process, the paint powder is applied to a substrate with an electrostatic spray gun. The carrier is pressurized air, rather than solvents. The powder coating adheres to the surface because of electrostatic forces. Excess powder that does not cling to the surface can be recycled. Heating in the curing oven ensures that the powder fuses to the surface. Powder coatings also can be applied using a fluidized bed process where the heated objects are immersed in the fluidized bed.

Because powder coatings contain no solvents, emissions of volatile organic compounds and the related air pollution problems are eliminated. Fire hazard and insurance rates are reduced and better neighborhood relations develop as the odor associated with solvent-based application are eliminated. Preliminary toxicological studies indicate that many of the commercial powder formulations are nontoxic. Since the overspray powder can be recycled, material use is high and solid waste generation is minimal. Waste disposal and liability problems are reduced. The process also has a high transfer efficiency, resulting in a lower reject ratio of parts. Coating quality is claimed to be better than with solvent-based coating. The messy cleanup operations associated with liquid-based paints are avoided. Powder coating is easier to apply and it is easier to train people to use it. The operators' attitudes improve. The operation is less labor intensive. Maintenance is easier and the overall operating costs are lower. Powder costs are minimally affected by petroleum prices and the operation is more flexible to changing coating requirements.

---

[71] ICF Associates, Inc.

A disadvantage of using powder coatings is that powder application equipment is more expensive to install than solvent-based or high solids coating equipment. Another disadvantage is that powder coating must be done at elevated temperatures, so it cannot be used on heat sensitive substrates such as plastics, wood, and assemblies containing nonmetal parts. Formulations with lower cure temperatures (275 °F) are being developed.[72]

Solvent-Based Paints - Product Substitution - Water-Based Formulations

Water-based formulations reduce the amount of solvents used and emitted in the coating process. Solvent-based paint equipment can easily be modified to apply water-based paints/coatings. The paint overspray can easily be collected with water in the spray booth and recycled. Though this also can be done in a solvent-based process, a difficult-to-treat aqueous waste stream may result due to direct contact with the solvent. Disposal and liability issues associated with wastes from the solvent-based formulation are reduced and the fire and explosion hazards present with the solvent-based process are eliminated. Concerns about worker exposure to solvents are also eliminated. Energy savings can be achieved by recirculating hot air in the ovens used to cure the paint. Similar recirculation is not possible in a solvent-based operation as the solvent levels in the recirculated air may reach explosive levels. The installed capital cost of water-based units is lower than that for high solids or powder coating.[73]

A number of private companies and a naval installation (Naval Air Rework Facility, Pensacola, Florida) have successfully converted from solvent-based painting to water-based painting operations.[74] Based on their experience, the annual cost to coat using water-based coating was higher compared to conventional solvent, high solids, or powder coating. The applied coating cost per square foot for a water-based unit is also higher and the coating may be inferior. The quality of water-based coatings varies with ambient conditions such as room temperature and humidity. The drying time is longer and could be a bottleneck in the production line. Water-based operations may necessitate installing a drying unit. Surface treatment procedures may need extensive modification to convert to a water-based coating method.[75]

One company that unsuccessfully tried to convert to water-based painting reported that the increased drying time led to production scheduling problems. The new system took several hours for drying, compared to the 30 minutes required for the solvent based process. It required an increased amount of surface cleaning before the water-

---

72 ICF Associates, Inc.

73 ICF Associates, Inc.

74 ICF Associates, Inc.

75 ICF Associates, Inc.

based coating could be applied. The time and cost involved in the extra cleaning were prohibitive. The water coating did not have the same hardness, durability, or gloss, and the quality of the water-based paint varied with room temperature and humidity. The company also reported that the water environment was corrosive to galvanized steel. The existing equipment made of galvanized steel needed to be replaced with stainless steel, which involved considerable expense.[76]

Solvent-Based Paints - Product Substitution - Radiation-Curable Coatings

Radiation-curable coatings do not contain solvents and therefore could be good substitutes. A liquid prepolymer is allowed to react with a thinner under ultraviolet light to form a coating. These coatings have been found to be effective on a number of surfaces.[77]

Paint Wastes - Better Operating Practices - Segregation

The current practice for disposing of residual paint left in cans is to pour it into drums containing thinner wastes. However, segregating paints from thinner wastes maintains the purity of the thinner and improves its recyclability. Thinners can be recycled onsite or offsite and reused in painting and cleaning processes.

Excess paints should be given to customers for touchup use, thus reducing the improper disposal of cans containing liquid paint with other nonhazardous wastes. (Cans containing dried paint residue can be thrown out.)

Solvent Wastes - Better Operating Practices - Adopt Good Manual Spraying Techniques

When manual spraying practices are used, the amount of waste produced can be reduced by using a 50 percent overlap in the spray pattern, maintaining a 6- to 8-in. distance between the spray gun and the surface, maintaining a gun speed of 250 ft/min, holding the gun perpendicular to the surface, and triggering at the beginning and end of each pass.[78] In addition to reducing the amount of waste produced, an increase in the production rate and a decrease in rejection rate can be realized.

---

[76] ICF Associates, Inc.

[77] M.E. Campbell and W.M. Glenn, *Profit from Pollution Prevention - A Guide to Industrial Waste Reduction and Recycling* (The Pollution Probe Foundation, Toronto, Canada, 1982).

[78] J. Kohl, P. Moses, and B. Triplett, *Managing and Recycling Solvents: North Carolina Practices, Facilities, and Regulations* (North Carolina State University, Raleigh, NC, 1984).

Solvent Wastes - Better Operating Practices - Avoid Adding Excess Thinner

The tendency to use excess thinners should be avoided. If the paint is difficult to apply, adding thinner may make it easy. However, adding excess thinner affects the film thickness, density, and durability.[79]

Solvent Wastes - Better Operating Practices - Avoid Excessive Air Pressures for Atomization

Using excessive air pressure to atomize paint particles leads to increased emissions and overspray, and should be avoided. Eliminating excessive air pressure can result in up to a 30 percent decrease in overspray and therefore a savings in raw material costs.[80]

Solvent Wastes - Better Operating Practices - Maintain Equipment Properly

Proper equipment maintenance is critical to reducing the number of reject products and improving productivity.[81] Proper maintenance also reduces the quantity of waste produced from paint stripping and repainting operations.

Solvent Wastes - Better Operating Practices - Lay Out Equipment Properly

Proper layout of equipment in a work area can also reduce emissions and improve the quality of the finished products. Solvent tanks must be kept away from heat sources such as curing ovens. This will help minimize evaporation of the solvents and will also prevent the solvent vapors from entering the curing oven and affecting the curing rate or decreasing the quality of the finish.[82]

Solvent Wastes - Better Operating Practices - Isolate Solvent-Based Spray Units From Water-Based Spray Units

Isolation of solvent-based spray units from water-based spray units is a good segregation practice. The oversprays from these operations should not be allowed to mix; the mixture could be classified as a hazardous waste. If the units are segregated, the filters from the water-based paint spray booths are not classified as hazardous waste.

---

[79] L.J. Durney, "How to Improve Your Paint Stripping," *Product Finishing* (1982), pp 52-53.

[80] ICF Associates, Inc.

[81] ICF Associates, Inc.

[82] ICF Associates, Inc.

Solvent Wastes - Better Operating Practices - Close Floor Drains in Production Area

Closing the floor drains will reduce the amount of water used to clean up spills. This practice promotes the use of rags that must be drycleaned. Thus, the generation of large quantities of rinse water containing solvents can be minimized.[83]

Solvent Wastes - Better Operating Practices - Purchase Proper Quantities of Paints

Buying paint in large containers rather than buying the same quantity in smaller containers will reduce the amount of residual materials. Large containers can be returned to manufacturers for cleaning and reuse. Ordering extra paint should also be avoided. Paint should be purchased based on the quantity needed to complete the job. This will reduce the amount of leftover paint and residue that must be disposed of.

Solvent Wastes - Better Operating Practices - Segregate Wastes

Segregating wastes is extremely important to reduce the amount of hazardous wastes generated and to improve the recyclability of solvents. If many solvents are used, they should be segregated. Some solvents can be directly reused in equipment cleaning operations.

Proper labels must be attached to containers. Hazardous wastes must be segregated from nonhazardous wastes and handled and disposed of properly. Labeling a container containing nonhazardous waste as hazardous can result in an unnecessary increase in disposal costs.

Solvent Wastes - Better Operating Practices - Standardize Solvent Use

Standardizing solvent use will reduce the numbers of different types of thinners and solvents used in coating formulations. If fewer solvents are stocked, the possibility of mixing of the wastes is reduced. Only one type of thinner or solvent corresponding to each type of paint should be purchased.

Solvent Wastes - Product Substitution - Use High-Solids Formulations

High-solids formulations contain a reduced quantity of solvent. Using high-solids formulations will therefore reduce the amounts of wastes and emissions generated from the painting operations.

---

[83] L.J. Durney.

Solvent Wastes - Process Change - Choose Proper Coating Equipment

The proper choice of coating equipment can reduce the quantity of wastes produced and result in raw material savings. Overspray from painting operations generates the most waste. Equipment with high transfer efficiencies should be chosen.

Solvent Wastes - Process Change - Replace Conventional Spray Units With Electrostatic Units

Electrostatic units (either centrifugally-atomized or air-atomized spray) have high transfer efficiencies. Converting from conventional equipment to electrostatic equipment may lead to a 40 percent reduction in overspray and considerable savings.[84] The overspray collects on electrically grounded spray booth walls. This reduces the amount of residues in the work area. The complete conversion will require significant time and work in testing, visiting other plants, engineering, and maintenance.

Solvent Wastes - Process Change - Replace Air-Spray Guns With Pressure Atomized Spray Guns

Replacing air-spray guns with air-less spray guns increases the transfer efficiencies. A 23 percent reduction in raw material costs has been reported, however the cleaning frequency had to be increased from once every 3 weeks to once a week.[85]

Aqueous Wastes - Process Change - Dry Paint Booths

Large volumes of wastewater are generated from "water curtain" paint booths. The water curtain is used to remove the paint overspray particulates from the exhaust system. A significant concentration of paint, solvents, and flocculating/coagulating agents accumulates in the wastewater. This wastewater must be treated to remove hazardous contaminants and the sludge must be disposed of as a hazardous waste.

Converting from a wet to a dry paint booth eliminates the problem of wastewater generation. In a dry booth, the contaminated air (laden with paint particles) is drawn through fibrous filters which must then be disposed of as hazardous waste. A much smaller volume of waste is generated. Results of a Navy study[86] indicate that converting to dry operation is technically feasible and cost effective (payback 8 months to 2 years) for small, medium, and large painting facilities.

---

[84] L.J. Durney.

[85] J. Kohl, P. Moses, and B. Triplett.

[86] Acurex Corporation, *Navy Paint Booth Conversion Feasibility Study*, CR 89.004 (Prepared for the Naval Civil Engineering Laboratory [NCEL], Port Hueneme, CA, 1989).

Recycling Onsite/Offsite

Paint Wastes - Onsite Recycling - Recycle Paint Overspray/Sludge

In water curtain spray booths, the overspray impinges on a water curtain. The paint/water mixture is then pumped to a separator. If the paints used are immiscible in water, they can be separated out and recycled. The water can also be recycled back into the water curtain. Recycling the water and paint reduces the amount of wastes produced and will reduce raw material costs.

Solvent Wastes - Onsite Recycling - Ultrafiltration, Distillation, or Evaporation

In ultrafiltration, the sludge containing solvents is filtered using membranes with pore sizes of 0.01 microns. Paint particles, usually larger than 1 micron, collect on the membranes and are removed continuously. A series of membranes filter the waste to produce a pure solvent that can be recycled.[87]

Distillation stills can be used to recover solvents. The solvent is indirectly heated and the vapors are condensed and collected. Purities of 90 to 99 percent can be obtained by this process. Table 17 lists manufacturers of distillation stills and associated costs. The concentrated still bottoms containing paint sludge must be shipped for proper disposal as a hazardous waste. Another possibility is to ship the still bottoms to a cement kiln for use as a supplemental fuel through a waste exchange program.

Evaporation, using drum-dryers or thin-film evaporators, is effective on heat-sensitive solvents. Large scale equipment is necessary for evaporation and, therefore, is cost effective only for large quantities of solvents. Many commercial solvent recyclers use agitated thin-film evaporators.

Solvent Wastes - Offsite Recycling - Closed-Loop Contract

Wastes consisting primarily of thinners, paint sludge, and paint can be reclaimed at an offsite facility. This closed-loop service is provided by many paint and thinner suppliers. Usually the purchase price includes delivery, waste hauling, recycling, and disposal. Such a service removes the wastes when it delivers the new product. The waste is processed at a licensed treatment, storage, and disposal (TSD) facility.

---

[87] Y. Isooka, Y. Imamura, and Y. Sakamoto, "Recovery and Reuse of Organic Solvent Solutions," *Metal Finishing* (June 1984), pp 113-118; W.H. Reay, "Solvent Recovery in the Paint Industry," *Paints & Resins* (March/April 1982), pp 41-44.

Processes used for recycling thinners are well-established and widely used.[88] Commercial recyclers have the versatility and have developed technologies for recycling large varieties of waste solvents. Between 70 and 80 percent of spent thinners can be recycled into a useful product.

Treatment

Solvent Waste - Onsite Pretreatment - Gravity Separation

Gravity separation is a relatively inexpensive option that is easy to implement. In this treatment process, the thinner and paint sludge mixture is allowed to separate by the force of gravity without external disturbance or agitation. The heavier paint sludge particles settle to the bottom of the container and the supernatant can be decanted off. The decanted thinner can be used as a "wash thinner" for cleaning equipment or for thinning primer and base coatings.[89]

Paint/Solvent/Aqueous Wastes - Offsite Treatment

Although most waste associated with paint can be treated using a number of different physical, chemical, and biological techniques, these techniques are not feasible for most Army installations that generate small quantities. Licensed TSD facilities, however, can use a number of processes such as activated carbon adsorption, chemical oxidation, solvent extraction, solid/liquid separation, stabilization/solidification, thermal destruction, volume reduction, and biological treatment. The applicability of each technique will not be discussed here.

---

[88] SCS Engineers, Inc., *Waste Audit Study - Automotive Paint Shops* (California Department of Health Services, January, 1987).

[89] SCS Engineers, Inc.

Table 20. Waste classification for paint removal, painting, and brush cleaning.

Materials used/ wastes produced	Waste Description: HW code	DOT shipping name	Hazard class	Number
Acetone	F003	Waste acetone	Flammable liquid	UN1090
Alcohols	D001	Waste alcohol, NOS	Flammable liquid	UN1987
Caustic paint stripper	D002	Waste paint related material	Corrosive material	NA1760
Chlorobenzene	F002	Waste chlorobenzene	Flammable liquid	UN1134
Enamel liquids	D001	Waste enamel	Combustible liquid	UN1263
Ethylene dichloride		Waste ethylene dichloride	Flammable liquid	UN1184
MEK	F005	Waste methylethylketone	Flammable liquid	UN1193
Methylene chloride stripper	F002	Waste methylene chloride	ORM-A	UN1593
Mineral spirits	D001	Waste naptha	Flammable liquid	UN2553
Paint dryer	None	Waste paint dryer, liquid	Combustible liquid	UN1263
Paint liquids	D001	Waste paint	Flammable liquid	UN1263
Paint solids (toxic)	Varies	Hazardous waste (solid), NOS	ORM-E (if solid)	UN9189
Paint thinners, lacquers	D001	Waste paint related material	Flammable liquid	NA1263
Paint waste with heavy metals	Varies	Hazardous waste liquid, NOS	ORM-E	NA9189
		Hazardous waste solid, NOS	ORM-E	NA9189
Petroleum distillates	D001	Waste petroleum distillate	Flammable liquid	UN1268
Toluene (Toluol)	F005	Waste toluene	Flammable liquid	UN1294
VM&P naphtha	D001	Compound, paint removing liquid	Flammable liquid	NA1142
Xylene (Xylol)	F003	Waste xylene	Flammable liquid	UN1307

7 Waste Minimization for Photography, Printing, and Arts/Crafts Shops

Photography and photoprocessing are common operations at Army installations. Some of the source types that use photography are training and audiovisual centers, hospitals, dental clinics, and research laboratories. Printing operations are limited to training and audiovisual centers. The materials used in producing a photograph are paper, plastic film, or a sheet of glass containing light-sensitive photographic emulsion. The emulsion is a gelatinous substance containing silver halides (chloride, bromide, and iodide). Some photographic films may be made of cellulose acetate; however, most are made of polyester. In photography, a negative containing different shadings is produced. The dark portions on a negative contain heavy deposits of silver. The processing that follows the exposure of a film or emulsion consists of developing, fixing, and washing. The primary wastestream of concern is wastewater containing photoprocessing chemicals and silver.

A printing process usually follows image processing, including typesetting and the photographic processing step discussed above. However, an intermediate step to prepare plates to carry the image to paper is necessary. A roller transfers ink onto a plate or a cylinder. The image on the plate or cylinder is transferred to a rubber blanket that in turn transfers it to paper. There are four different types of image carriers: manual, for screen printing; mechanical, for relief printing; electrostatic, for offset duplicating; and photomechanical, for platemaking.[90] Preparation of plates is followed by printing. Two common types of printing presses used are sheet-fed presses that can print up to 3 impressions per second and web presses that operate at the rate of 1000 to 1600 feet per minute.[91]

In the printing process, the plate (a thin aluminum sheet) is first attached to the plate cylinder of the press. Each unit of a printing press prints a single color; four units (red, blue, yellow, and black) are required for a full-color illustration. The raw materials typically used in a printing operation are ink, paper or other print substrate, and fountain solution. Wastes generated from a printing process include waste inks,

90 Jacobs Engineering Group, Inc., *Waste Audit Study - Commercial Printing Industry* (California Department of Health Services, Sacramento, CA, May 1988).

91 Jacobs Engineering Group, Inc.

used ink containers, used plates, damaged or worn rubber image transfer blankets, waste press oils, cleanup solvents, rags, and trash.[92]

The arts and crafts shops are educational and vocational shops that provide training in automobile maintenance/repair, metalworking, graphic arts, and woodworking. Only the minimization of wastes from the photography and printing section of arts and crafts shops is considered in this chapter. Minimization of wastes from automobile maintenance/repair and metalworking are discussed in Chapters 4 and 5, respectively. A summary of processes and their corresponding waste streams is provided in Table 21.

Source Reduction - Photography and Printing Operations

All Wastes - Better Operating Practices - Proper Material Handling and Storage

Raw materials may become obsolete and spoil due to improper storage and handling. Proper storage and handling will reduce the amount of waste generated and reduce raw material costs. Photographic and printing chemicals are sensitive to light and temperature. Proper storage under recommended conditions will increase their shelf life and result in savings in raw materials costs and disposal costs.

Storage areas must be kept clean. One way to keep storage areas clean is to prohibit through traffic and restrict entry. Traffic increases the amount of dirt and the possibility of contamination. Spills can be controlled and contained more easily if entry is restricted to only a few persons.

Proper inventory control will reduce disposal of material with an expired shelf life. The materials should be used and distributed in the order they are received. Computerized inventory control and materials tracking will help manage the inventory.

Material with an expired shelf life should not be discarded. It should be tested to determine if it can still be used. Unusable material should be recycled through a manufacturer or a waste exchange.

The installation should avoid ordering excess material. Material ordering should be based on use. Small printing operations should purchase inks in small containers to limit the possibility of the ink spoiling in large containers that may not be properly

92 Jacobs Engineering Group, Inc.

sealed. Large printing operations should order materials in large containers that can be returned to manufacturers for cleaning and reuse.

Raw materials should be inspected upon arrival and before use. Unacceptable and/or damaged items must be returned to manufacturers to avoid disposal problems and to avoid creating defective products.

Source Reduction - Photographic Operations

Photographic Chemicals - Better Operating Practices - Proper Chemical Storage

Many photographic chemicals degrade in the presence of air. Small photographic operations should store chemicals in plastic containers. Adding glass beads to the containers to bring the liquid level up to the brim has been found to be useful.[93] The life of the chemicals can thus be extended.

Photographic Films - Material Substitution - Nonsilver Films

Substituting films containing silver with those containing nonhazardous chemicals reduces hazardous waste generation. The silver from silver films makes the photographic wastes (e.g., fixing bath solutions, rinse water, etc.) hazardous. Only very low silver concentrations are allowed in wastewaters treated at wastewater treatment plants operated by county sanitation districts.

Some substitutes to silver-halide films include vesicular (diazo), photopolymeric, and electrostatic films.[94] The disadvantage of these films is that they are slower than silver films. Vesicular films consist of a honeycomb structure and are constructed from a polyester base coated with a thermoplastic resin. These films are also coated with a light-sensitive diazonium salt. Photopolymeric films use carbon black instead of silver. A weak alkaline solution is used to process these films. The spent bath solution is a nonhazardous waste that can be neutralized before disposal. An electrostatic charge makes electrostatic film light sensitive. The speed of this nonsilver film is comparable to silver films and it has a high resolution.

---

93 Jacobs Engineering Group, Inc.

94 Jacobs Engineering Group, Inc.

Other Photographic Wastes - Material Substitution

Other photographic wastes such as intensifiers and reducers also contain hazardous compounds (e.g., mercury, cyanide salts, etc.). Use of available nonhazardous substitutes will reduce the amount of hazardous wastes generated.

Fixing Bath Solutions - Process Change - Extended Bath Life

The life of fixing baths can be extended to reduce the quantities of wastes generated from photographic operations. Adding ammonium thiosulfate will increase the bath life by doubling the allowable silver concentration. An acidic stop-bath can be used before the fixing bath. Acetic acid can be added to the fixing bath to keep the pH low.[95]

Photographic Wastewater - Process Change - Reduction in Water Use

Parallel rinsing is commonly used in photographic processing operations. Converting to countercurrent rinsing reduces the amount of wastewater generated. In countercurrent rinsing, the water flows in a direction that is opposite to the film movement. Thus, fresh water in the final tank is used in the final film washing stage after most of the contamination has been rinsed off. The most contaminated water is in the very first washing stage. A countercurrent system, however, requires more equipment and space.

Sponges or squeegees should be used in nonautomated operations to remove excess water from the films. This can reduce the dragout of chemicals from one tank to another by almost 50 percent.[96] Some of the advantages of minimizing contamination of processing baths are increasing the recyclability of solutions, extending solution life, and reducing the quantities of raw materials (replenishments) required.

Another method of reducing waste chemicals is to properly monitor the chemical concentrations of baths and add accurate quantities of replenishment chemicals. Exposing the process baths to air should be minimized to prevent oxidation reactions.

All Photographic Wastes - Process Change

Recent advances in desk top publishing systems and the use of personal computers are making "electronic prepress photographic systems" increasingly popular. In these systems the graphics, photographs, and layouts are scanned into the computer.

---

[95] Jacobs Engineering Group, Inc.

[96] Jacobs Engineering Group, Inc.

Editing is performed on the computer rather than on paper. Only the final version is printed on paper. Use of electronic systems will greatly reduce the quantities of wastes generated from photographic operations at printing facilities.

Source Reduction - Printing Operations

Metal Etching/Plating Wastes - Process Change

If printing operations include metal etching and plating, alternative processes (e.g., lithographic plate, hot metal, flexographic, etc.) must be examined as substitutes. These alternative processes eliminate the problems associated with treatment and disposal of hazardous wastes from metal etching and plating.

Metal Etching and Plating Wastewater - Process Change - Reducing Water Use

The wastewater produced from metal etching and plating is a hazardous waste. Reducing the dragout from process tanks and using countercurrent rinsing will reduce the toxicity of the wastewater. Dragout reduction can be achieved by positioning parts on racks so they drain properly, using drip bars and drain boards to collect the dragged-out chemicals and returning them to the process tanks, and increasing the process tank temperature to reduce the surface tension of the solution and minimize its tendency to cling to parts. Countercurrent rinsing reduces the quantity of wastewater leaving an operation, but does not reduce the hazardous material content in wastewater.

Lithographic Plate Processing Chemicals - Better Operating Practices - Reduced Chemicals Use

Bath life can be extended and changing of solutions can be reduced to only a few times a year by frequently monitoring the pH, temperature, and chemical concentration of the bath. Using automatic plate processors facilitates precise monitoring of bath conditions.

Lithographic Plate Processing Plates - Better Operating Practices - Proper Storage/Recycling

Proper storing of plates reduces the possibility of spoiling and maintains their effectiveness. Used plates are not a hazardous waste. They should be collected and sold to an aluminum recycler.

Lithographic Plate Processing Plates - Material Substitution

Alternative presensitized plates are available that can be processed with water. Other plates available include Hydrolith plates manufactured by 3M Corporation.[97] 3M has also developed a platemaking system that eliminates the need for photoprocessing and has been found to be economical for large plating operations.[98]

Web Press Wastes - Process Change - Break Detectors

Web break detectors detect tears in a web as it passes through a high speed press. Broken webs tend to wrap around rollers and force them out of their bearings. Using break detectors in web presses prevents severe damage to the presses and also reduces the quantities of wastes from spillage of inks, fountain solutions, and lubricating oil.

Waste Inks/Cleaning Solvents/Rags - Better Operating Practices

Rags dampened with cleaning solvents are used to clean presses. The amount of solvent and number of rags used can be minimized by reducing the cleaning frequency and by properly scheduling cleaning. Ink fountains must be cleaned only when a different color ink is used or if the ink has dried out. Ink fountains can be prevented from drying out by using compounds that are dispensed as aerosol sprays.[99]

Waste Inks - Better Operating Practices

The amount of waste ink generated can be reduced by implementing better operating practices. Only the required amount of ink should be put in an ink fountain before starting a print job. Resealing the ink containers after use prevents contamination by dust/dirt, formation of a skin on the ink surface, loss of solvents, and hardening. As much ink as possible should be scraped from the container for use. Automatic ink levelers, when used in large presses, improve the print quality and reduce the amount of trash and the likelihood of accidental spills.

Waste (Flexographic) Inks - Product Substitution - Water-Based Inks

Substituting water-based inks for solvent-based inks in flexographic printing reduces the quantity of hazardous wastes generated. Use of water-based inks also eliminates the problems encountered with volatilization of solvents. Some disadvantages of

---

97 M.E. Campbell and W.M. Glenn.
98 M.E. Campbell and W.M. Glenn.
99 Jacobs Engineering Group, Inc.

water-based inks are the limited range of colors, higher energy requirement for drying due to high heat of vaporization, higher equipment operating costs, reduced printing capacity and speed, and difficult cleaning requirements.[100]

Waste Inks - Product Substitution - UV Inks

Ultraviolet (UV) inks are those that dry when exposed to UV light. UV inks contain monomers, photosynthesizers, and pigments rather than solvents. Since they do not dry in fountains, cleaning requirements are reduced. There are several advantages of UV inks:

1. UV inks eliminate "set-off," the unintentional transfer of ink from one sheet to the back of the preceding sheet after the sheets have been stacked that occurs when the ink has not completely dried.
2. UV inks eliminate the need for anti-offset sprays that prevent set-off.
3. UV inks eliminate the need for ventilated storage of sheets when using oxidative drying processes.[101]

There are also disadvantages to using UV inks:

1. The cost is 75 to 100 percent higher than conventional heat-set inks.
2. UV light is a hazard to plant personnel.
3. The interaction of UV light and atmospheric oxygen forms ozone.
4. Conventional paper recycling procedures will not deink paper printed by this process. This creates a waste source from an otherwise recyclable material.
5. Some of the chemicals in the inks are toxic.[102]

Waste Inks - Product Substitution - Heat Reactive Inks (Web Presses)

Heat reactive inks contain a prepolymer, a cross-linking resin, and a catalyst. At 350 °F, the inks are activated to polymerize and set. These inks contain much less solvent than the conventional heat-set inks.

---

[100] Jacobs Engineering Group, Inc.
[101] Jacobs Engineering Group, Inc.
[102] Jacobs Engineering Group, Inc.

Cleaning Solvents - Good Operating Practices

Whenever possible, pour-cleaning with solvent followed by wipe cleaning with a rag could be used to clean presses. The drained solvent should be collected and recycled. Although more solvent is used in this process, less ink ends up on the rags. Cross-contamination of inks must be avoided. The used solvent can be used to clean rollers and blankets to reduce the amount of fresh solvent used.

Use of wipe cleaning with rags may be preferable to pour-cleaning in some cases because the quantity of solvent wastes is considerably reduced.

Detergents or soap solutions rather than solvents should be used for general cleaning. Use of solvents should be limited to removing inks and oils.

Cleaning Solvents - Product Substitution - Nonhazardous Formulations

Hazardous materials such as benzene, carbon tetrachloride, TCE, and methanol were previously used as cleaning solvents. Several blanket washes containing glycol ethers and other heavy hydrocarbons that are less toxic and flammable are now available. Using nonhazardous blanket washes is recommended for all cleaning requirements in a printing operation.

Fountain Solutions - Product Substitution

Conventional fountain solutions contain water, isopropyl alcohol, gum arabic, and phosphoric acid. These compounds are transferred to the printing paper or they evaporate causing volatile organic compounds to be released. Substitute formulations should be used to reduce the emissions.

Waste Paper - Good Operating Practices - Reduce Use

Printing operations generate a large quantity of waste paper. Although paper is not a hazardous waste, reducing paper consumption and thus the purchase of new paper is a good operating practice.

Recycling Onsite/Offsite - Photographic Operations

Spent Fixing Bath Solution - Onsite Recycling - Silver Recovery

Spent fixing bath solutions contain silver that can be recovered. Following recovery, the bath can be reused or discharged to a sewer. Recovering silver from the solution will reduce the amount of hazardous silver compounds in wastewaters, extend the useful life of fixing baths, and provide a potential source of income from selling the captured silver to a precious metal reclaimer.[103]

Electrolytic deposition is the most common method of recovering silver. The electrolytic recovery units have carbon anodes and steel cathodes. Applying a low voltage results in the plating of metallic silver on the cathode. The fixing bath solution, after silver removal, can be mixed with fresh solution and reused in the photographic development process.

A second method of silver recovery is the use of steel wool cartridges to replace silver in an oxidation-reduction reaction. In this process, the spent fixing bath solution is pumped through the steel wool cartridge and iron replaces silver in the solution. Silver sludge settles to the bottom of the cartridge.

A detailed discussion of methods and procedures for silver recovery are outlined in the Defense Logistics Agency's *Defense Utilization Disposal Manual*.[104] This source includes general procedures for hypo collection and recovery, procedures for removing silver from recovery units, recommended recovery procedures for use with automatic film processors, and procedures for using the metallic replacement recovery cartridges.

If spent fixing bath solutions are shipped offsite they should be labeled and manifested as hazardous waste and count against the facilities HW generation. This option is not recommended.

Photographic Films - Offsite Recycling - Silver Recovery

Photographic laboratories and many other facilities that use X-ray films generate used photographic films that contain 1 percent (0.15 troy ounces) of silver.[105] These films can be sold to recyclers for silver recovery.

---

[103] Jacobs Engineering Group, Inc.

[104] *Defense Utilization and Disposal Manual*, DOD 41620.21-M (Defense Logistics Agency, Office of the Assistant Secretary of Defense, Alexandria, VA, September 1982), pp VI-42 and XVII-A-5 through XVII-A-10.

[105] *Defense Utilization and Disposal Manual.*

Recycling Onsite/Offsite - Printing Operations

Metal Etching and Plating Wastewater/Sludge - Onsite/Offsite Recycling - Material Recovery

The wastewater from metal etching and plating operations contains heavy metals and various quantities of process chemicals. Material recovery processes can be implemented to recover some of the process chemicals and thus reduce raw material costs.

Used Metal Wastes - Offsite Recycling

Linotype operations used for letterpress printing generate used metal wastes. The process uses an alloy with a low melting point to create the letters in lines of text. The metal must be melted in the linotype machines and/or recycled. The manufacturer or metal supplier may be willing to buy the used metal and recycle it.

Waste Inks - Onsite Recycling

A simple recycling technique is to blend all the waste inks together to form black ink. It may be necessary to add small amounts of color and toner to obtain an acceptable black color. The reformulated black ink is similar in quality to new newspaper ink. Most newspaper printing presses use recycled black ink.[106]

Waste Inks - Offsite Recycling

Contract recycling of waste inks can be used to produce black ink. This black ink can be used to print newspapers or flyers. In such a contract, waste inks are bottled and shipped to the recycler (or manufacturer) and the reformulated black ink is shipped back. This will reduce the costs of buying new black inks and disposing of waste inks.

Cleaning Solvents - Onsite Recycling - Distillation

Small distillation units are available for recycling solvent used in pour-cleaning. Proper segregation of solvents and trash is necessary. Still bottoms must be disposed of as hazardous waste.

---

[106] C. Woodhouse, *Waste Ink Reclamation Project* (California Department of Health Services, Toxic Substances Control Division, August 1984).

Waste Paper - Offsite Recycling

Waste paper should be collected and recycled. Manufacturers or paper recyclers remove the ink and repulp the paper. Pulp from recycled paper adds strength and durability to many other paper products.

Treatment - Printing Operations

Wastewater from metal etching and plating operations is classified as hazardous and must be treated before discharge to a municipal sewer. If not treated, it must be put in drums and disposed of as hazardous waste. Packaged treatment units that neutralize and precipitate the heavy metals are available. The sludge generated from treatment is also a hazardous waste and is banned from land disposal.

Table 21. Typical PPAS operations, materials used, and wastes generated.*

Process/Operation	Materials Used	Ingredients	Wastes Generated
Apply light sensitive coating	resins, binders, emulsion, photosensitizers, gelatin, photoinitiators	PVA/ammonium dichromate, polyvinyl cinnamate, fish glue/albumin, silver halide/gelatin emulsion, gum arabic/ammonium dichromate	photographic waste
Develop plates	developer	lactic acid, zinc chloride, magnesium chloride	photographic waste
Wash/clean plates	alcohols, solvents	ethyl alcohol, isopropyl alcohol, methyl ethyl ketone, trichloroethylene, perchloroethylene	spent solvents
Apply lacquer	resins, solvents, vinyl lacquer	PVC, PVA, maleic acid, methyl ethyl ketone	spent solvents
Counter-etch to remove oxide	phosphoric acid	phosphoric acid	acid/alkaline wastes
Deep-etch coating of plates	deep etch bath	ammonium dichromate, ammonium hydroxide	acid/alkaline waste, heavy metal solutions, waste etch bath
Etch baths	etch bath for plates	ferric chloride (copper), aluminum chloride/zinc chloride/hydrochloric acid (chromium), nitric acid (zinc, magnesium)	waste etch bath, acid/alkaline waste, heavy metal solutions
Printing (Ink)	pigments, dyes, varnish, drier, extender, modifier	titanium oxide, iron blues, molybdated chrome orange, phthalocyanine pigments, oils, hydrocarbon solvents, waxes, cobalt/zinc, magneze oleates, plasticizers	waste ink with solvents/heavy metal, ink sludge with chromium/lead
Making gravure cylinders	acid plating bath	copper hydrochloric acid	spent plating waste

* Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., chicago, IL, 1986), pp 146-147.

8 Waste Minimization for Hospitals, Clinics, and Laboratories

Army hospitals, veterinary clinics, dental clinics, and other laboratories are usually tenants located on an installation. The types of wastes generated by these activities can be divided into infectious wastes (IW), pathological wastes (PW), sharps, pharmaceutical wastes (PhW), radioactive wastes (RW), laboratory wastes (LW), chemotherapy wastes (CW), infectious linen (IL), and general wastes (GW). Only the LW and CW are hazardous wastes by the RCRA and HSWA definition.

For this discussion, some of the definitions for hospital wastes are extracted from Army Regulation (AR) 40-5.[107] Detailed definitions and classifications of infectious wastes can be obtained from USEPA's *Guide to Infectious Waste Management*.[108]

IW are wastes from patients in strict or respiratory isolation, or with wound and skin precautions; wastes from microbiological laboratories; and surgical waste (at the discretion of the operating room supervisor). PW includes anatomical parts, excluding human corpses and animal carcasses. Sharps include discarded hypodermic needles, syringes, pipettes, broken glass, and scalpel blades that pose infection and physical injury hazards through cuts or puncture wounds. GW is all the waste not classified as infectious, pathological, or hazardous. Examples of GW are refuse generated from general patient units, emergency rooms, dental areas, surgical suites, administrative areas, and supply areas. PhW consists primarily of outdated medicines (drugs, vaccines, and physiological solutions). RW emit ionizing radiation (such as alpha, beta, gamma, or X-rays).

The activities that generate most of the highly infectious wastes are general surgery/recovery, vascular surgery, plastic surgery, pathology, blood banks, microbiology laboratories, labor and delivery rooms, obstetrics, emergency room isolation, and the morgue. Highly infectious wastes generated are significant laboratory waste, including all tissue or blood elements, excreta, and secretions obtained from patients or laboratory animals and disposable fomites (items that may harbor or transmit pathogenic organisms); surgical specimens and attendant

[107] Army Regulation (AR) 40-5, *Preventive Medicine* (HQDA, 30 August 1986).

[108] *Guide to Infectious Waste Management*, EPA/530-SW-86-014 (USEPA, Washington, D.C., 1986).

disposable fomites; disposable materials from outpatient areas and emergency departments; equipment, instruments, utensils, and fomites of a disposable nature from isolation rooms; animal feces, animal bedding, supplies, and fomites resulting from and/or exposed to infectious animal care and laboratory procedures; and all disposable needles and syringes.[109]

Radioactive wastes are usually generated by the radiology ward, nuclear medicine, clinical pathology, and laboratories that use radionuclides. Some of the radionuclides administered to patients during treatment include $^{99\text{-}M}$Technetium, ^{51}Chromium, ^{32}Phosphorus, and ^{131}Iodine.[110] Most of the radioactive wastes that require special handling and disposal are generated by the use of radionuclides such as ^{14}Carbon, ^{4}Hydrogen, and ^{131}Iodine, in clinical laboratories.

A number of different types of hazardous wastes are generated in HCL, usually in small quantities. LW is mostly chemical wastes, including ignitable/chlorinated solvents and miscellaneous used chemicals (e.g., xylene, formalin, mercury, etc.) generated in analytical and clinical laboratories. These wastes may also be generated in maintenance, pharmacy, and nursing areas. Photographic films and chemicals are used in radiology. Other toxics and corrosives are used throughout the hospitals.

CW is a large quantity HW generated by the use of antineoplastic, or cytotoxic agents in chemotherapy solutions administered to patients. The chemicals are typically only a small volume of the waste. Most of the waste consists of protective clothing and gauze pads that are lightly contaminated.

Most of the guidance on proper management and minimization of wastes discussed in this chapter has been obtained from *Protocol Health Care Facility Waste Management Surveys*,[111] and *Waste Audit Study - General Medical and Surgical Hospitals*.[112] The minimization of photographic wastes is discussed in Chapter 7.

Regulations

On October 21, 1988, the U.S. Congress passed the Medical Waste Sanctions Act (MWSA), which strictly controls generation and disposal of medical wastes and

---

109 D. Kraybill, T. Mullen, and B.A. Donahue, *Hazardous Waste Surveys of Two Army Installations and an Army Hospital*, Technical Report N-90/ADA088260 (USACERL, August 1980), pp 46-48.

110 D. Kraybill, T. Mullen, and B.A. Donahue.

111 *Protocol Health Care Facility Waste Management Surveys* (USAEHA, 1987).

112 Ecology and Environment, Inc., *Waste Audit Study - General Medical and Surgical Hospitals* (California Department of Health Services, Sacramento, CA, 1988).

prohibits dumping these wastes in oceans and large water bodies (such as the Great Lakes).[113] MWSA was initiated as an amendment to the original Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972. MPRSA and MWSA define medical waste to include "isolation wastes; infectious agents; human blood and blood products; pathological wastes; sharps; body parts; contaminated bedding; surgical wastes and potentially contaminated laboratory wastes; dialysis wastes; and other equipment and material that the Administrator of the USEPA determines may pose a risk to public health, welfare, or the marine or Great Lakes environment."[114] Of the 160 million tons of waste generated in the United States each year, 3.2 million tons are medical wastes from hospitals. These medical wastes do not include refuse from doctors' offices, laboratories, home health care, veterinary clinics, and blood banks. Of the 3.2 million tons of medical wastes, USEPA estimates that 10 to 15 percent are infectious.

MWSA was passed because medical wastes could be regulated under the RCRA and HSWA but are not under the USEPA rules. MWSA requires USEPA to develop rules and regulations for a cradle-to-grave manifest system to track the medical wastes from generation to disposal; recordkeeping, reporting, and proper segregation from ordinary refuse; and disposal requirements. The States have been given the authority to enforce MWSA more stringently than the USEPA requirements. States such as Delaware, Louisiana, Maryland, Minnesota, New York, and Pennsylvania have passed stricter laws for tracking and disposing of medical wastes.

In the private sector, research and testing laboratories such as those located in Army hospitals and associated research facilities would be regulated as small quantity generators of hazardous laboratory waste. All the rules of RCRA and HSWA would apply and cradle-to-grave management and development of minimization strategies would be necessary.

---

113 *Medical Waste Sanctions Act of 1988*, Report 100-1102 (House of Representatives, 100th Congress, October 1988).

114 *Medical Waste Sanctions Act of 1988.*

Source Reduction

IW/PW/GW/Sharps - Better Operating Practices - Segregation

IW and PW must be segregated from GW and sharps. GW such as surgical glove wrappers should not be placed in IW containers (e.g., red bags in rigid containers). Sharps must be placed in separate containers (e.g., rigid plastic boxes) in every room where they are used. Separate containers (e.g., yellow or white bags) must be used for general wastes including paper and trash.

IW/PW - Better Operating Practices - Segregation/Labeling

All the containers must be rigid and must be lined with impervious, tear resistant, and distinctively colored bags (e.g., red bags for infectious wastes only). The same type and color bags must be used at all waste generation points and marked/labeled with the universal biohazard symbol. Standardized procedures (labeling, color, etc.) reduce confusion among personnel and improve waste management, thus, minimizing quantities of wastes generated.

IW/PW - Better Operating Practices - Collection/Transportation

Sufficient numbers of IW/PW containers must be provided and conveniently located in all rooms where the wastes are generated. They should also be located in such a way as to minimize patients/personnel exposure to the wastes. The containers must be cleaned and disinfected every time they are emptied. All the containers should have tight-fitting lids and the lids should be in place when the containers are not in use. To minimize exposure for patients and staff, IW/PW must be collected frequently from all the generation points by trained personnel only. The transport containers must have tight-fitting lids and should be used exclusively for IW/PW. The interior of the transport containers must be cleaned and disinfected regularly.

IW/PW - Better Operating Practices - Storage

All IW/PW storage areas (including access doors, containers, freezers, refrigerators, etc.) must be labeled and marked with the universal biohazard symbol.

Sharps - Better Operating Practices - Disposal

Clipping needles after use is prohibited by AR 40-5 to prevent generation of pathogen-containing aerosols. Used syringes must be placed only in rigid impervious containers marked with the universal biohazard symbol. Adequate containers must be provided and managed by trained personnel.

HW - Better Operating Practices - Inventory

A current and comprehensive inventory should be developed for all the hazardous materials used and hazardous wastes generated. The inventory should contain the following for each HW: a description; hazard code; USEPA (or State) number; physical form; rate of generation; method of treatment, storage, and disposal; and an indication if the waste is infectious. All HW on the inventory must be reviewed annually and reported to the installation environmental office.

Infectious hazardous wastes could be generated at the histology (waste xylene), parasitology (hazardous fluids), and radiology (waste barium) laboratories. A proper inventory must be developed for these wastes. The procedures for handling these wastes are outlined in *Infectious Hazardous Waste Handling and Disposal.*[115]

HW - Better Operating Practices - Proper Storage

Proper containers must be used to store hazardous wastes. They must be properly labeled, and contain liners compatible with the wastes. Upon exceeding the 55-gal (or 1 qt for acute HW) storage limit in the satellite accumulation areas, the 90-day temporary storage requirements[116] must be complied with and the wastes must be taken to the installation's hazardous waste storage building.

HW (solvents) - Better Operating Practices - Segregation

Solvent wastes must be segregated according to the recycling or treatment processes used for their recovery or disposal. Some of the criteria useful for segregation are flash point, Btu value, viscosity, halogen content (e.g., chlorine), and water content.[117] Segregating wastes as individual chemicals (with minimal contamination) simplifies waste management.

HW (solvents) - Product Substitution

Nonhalogenated solvents should be substituted for halogenated solvents (e.g., TCE, 1,1,1-trichloroethane, MC, etc.). Simple alcohols and ketones are good substitutes for

---

115 *Infectious Hazardous Waste Handling and Disposal*, Technical Guide Number 147 (USAEHA, 1986).

116 40 CFR 262.34, *Onsite Accumulation Requirements.*

117 Ecology and Environment, Inc., pp 5-1 -- 5-3.

petroleum hydrocarbons (e.g., toluene, xylene, etc.). Aqueous reagents should be used whenever possible. Use of a nonhazardous substitute (such as Histoclear™) for xylene used as a tissue clearing agent should be examined to determine its effectiveness. Feasible substitutions can be determined by laboratory managers on a case-by-case basis.

HW (solvents) - Process Change

Cleaning processes that use alcohol-based disinfectants can be modified to use ultrasonic or steam cleaning methods. Premixed containerized test kits should be used for solvent fixation (making slides). Calibrated solvent dispensers should be used for routine tests. Minimizing the sizes of cultures or specimens in the pathology, histology, and other laboratories, minimizes the quantities of solvent wastes produced.

Modifying laboratory methodologies to use modern technologies (e.g., monoclonal antibodies, radioisotope labeled immunoassays, and ultrasensitive analytical devices) minimizes or even eliminates the need for extractions and fixation with solvents. Sensitive analytical equipment can reduce analyte volume requirements.

LW - Better Operating Practices - Disposal

All the laboratory hazardous wastes that may be discharged into the sanitary sewer must be identified. Approval must also be obtained from local authorities. According to USEPA requirements [40 CFR 261.3(a)(2)(iv)(E)] the following conditions must be met:

1. Only low toxic hazard, and biodegradable wastes may be discharged,
2. The annualized average flow rate of laboratory wastewater must not exceed 1 percent of the total wastewater flow into the inflow of the wastewater treatment plant,
3. The combined annualized average concentration must not exceed one part per million (ppm) of the inflow to the wastewater treatment plant.

Proper standing operating procedures (SOPs) must be developed and used for disposal of chemicals in the sanitary sewer system.[118] Disposal actions must be coordinated with the installation's environmental office. Sewer disposal is not an environmentally sound practice and should be avoided.

---

[118] National Research Council, *Prudent Practices for Disposal of Chemicals from Laboratories* (National Academy Press, Washington, DC, 1983).

HW (mercury) - Better Operating Practices

Waste mercury can be recycled and must be recovered from spills and from crevices of broken devices. All the residual mercury contained in broken thermometers, blood pressure reservoirs, or other devices should be drained. Proper spill cleanup and handling operations must be designed to protect employees. Special mercury vacuums and spill absorbing kits are available.

HW (mercury) - Process Change

Many hospitals in the United States are using electronic piezometric sensing devices instead of mercury-based thermometers and blood pressure instruments. Such a substitution eliminates both the hazards and cleanup costs associated with broken glass and spilled mercury.

HW (formaldehyde) - Better Operating Practices

Reducing both the cleaning frequency of hemodialysis and RO water supply equipment and the solution strength will minimize the quantities of waste formaldehyde generated. The membranes used in RO units must occasionally be flushed with formalin. A laboratory standard for formalin solutions should be developed based on microbial culture studies that compare microbial residue with variations in strength, cleaning frequency, and water supply systems.[119]

HW (formaldehyde) - Process Change

The dialysis equipment used in the hospital can be used to capture and concentrate waste formalin (containing 4 percent formaldehyde, 1 percent methanol, and 95 percent water).[120] Formaldehyde extracted and concentrated with the used dialysis membranes can then be sent for proper disposal (e.g., incineration) thus minimizing the waste and associated costs.

CW - Better Operating Practices - Collection/Disposal

Special dedicated containers must be used to collect antineoplastics, cytotoxins (cancer treatment agents), and other controlled drugs. Many of these drugs are listed hazardous wastes and must be managed using proper turn-in procedures.

---

[119] Ecology and Environment, Inc.

[120] Ecology and Environment, Inc.

CW - Better Operating Practices

Segregation of CW from other wastes is an effective minimization practice. Personnel must be properly trained and separate containers (with distinct labels) should be placed in all the drug handling areas.

The cleaning frequency for hoods used for compounding drugs should be reduced. According to OSHA recommendations, hoods should be wiped down daily with 70 percent alcohol and decontaminated weekly with an alkaline solution.[121] However, the actual cleaning frequency must be determined based on the use and amount of spillage in the hood.

Spill cleanup kits, for small and large spills, must be readily available in the drug compounding and use areas. The garments, except gloves, worn by employees should be disposed of with nonhazardous refuse if no spills occurred.

The location of compounding and administration areas should be centralized to minimize spillage and exposure hazards. Drug purchases must be controlled such that only the appropriate container sizes are procured and no residue is left for disposal. Outdated drugs should be returned to the manufacturer.

CW - Product Substitution

Antineoplastics and cytotoxic agents are highly toxic and environmentally persistent. They should be substituted with biodegradable drugs. In some cases, the shelf life can be used as an indicator of environmental persistence. Doctors and pharmacists must be encouraged to choose less environmentally hazardous drugs of equal effectiveness.

RW - Product Substitution

A knowledge of the properties of radionuclides is required for the minimization of RW. If possible, a stable radionuclide with a short half-life, low energy, nontoxic decay product, and minimal extraneous radiation emissions should be chosen. Extraneous radiation is the radiation generated that is not required in a test or procedure. If a beta emitter is required, a radionuclide with minimal gamma emissions must be chosen. Containment of gamma rays is difficult.

---

[121] Ecology and Environment, Inc.

A radiation safety committee should be established to advise researchers about alternative isotopes that are less environmentally hazardous than those currently in use.

RW (^{226}Radium) - Product Substitution

^{226}Radium is the most hazardous radionuclide used for cancer treatment in hospitals. It has a very long half-life and its decay products are unstable. ^{192}Iridium or ^{137}Cesium needles have been found to be good substitutes for ^{226}Radium needles.[122]

Recycling Onsite/Offsite

HW (xylene, other solvents) - Recycle Onsite - Distillation

All the spent solvents generated in the laboratories should be accumulated in proper segregated containers. The recyclability of solvents is greater if contamination is minimal. Small distillation stills can be used to recover solvents for reuse.

For laboratories, stills made of glassware (process-spinning band distillation[123]) may be more suitable. Appropriate manufacturers (e.g., B/R Instrument Corporation, P.O. Box 7, Pasadena, MD 21122; [301] 647-2894) should be contacted for information on technical feasibility and costs.

Xylene wastes generated at the hospitals are contaminated with paraffin and tissue samples, and their recyclability depends on the content of the contaminants. Small stills can be used to distill out pure xylene for reuse. The still bottoms must be properly disposed of as HW. The still can also be used to recycle other solvents (e.g., ethanol).

HW (solvents) - Offsite Recycling

A number of commercial recyclers process solvents for reuse. See Chapter 4 for more information.

[122] Ecology and Environment, Inc.

[123] L.M. Gibbs, "Recovery of Waste Organic Solvents in a Health Care Institution," *American Clinical Products Review* (November/December 1983).

HW (mercury) - Offsite Recycling

If more than 10 lb of liquid mercury is accumulated, it can be sold to a commercial reprocessor.[124] Large quantities can be sent in standard (76-lb) flasks supplied by the reprocessor. These reprocessors are willing to purchase from institutions rather than individuals. Therefore, DRMO must pursue this option for Army installation generators such as hospitals and laboratories.

HW (formaldehyde) - Onsite Recycling - Reuse

Direct reuse of formaldehyde solutions in autopsy and pathology laboratories is possible, depending on the type of specimen. Reuse is possible because the specimen holding times are short and formalin solutions retain their properties for a long time. Additionally, the desired preservative properties may be more effective at lower concentrations than the 10 percent formaldehyde solutions commonly used in pathology laboratories.[125] Minimum effective strength of formalin solutions should be determined based on microbial culture studies.

HW (photographic chemicals) - Recycle Onsite/Offsite - Silver Recovery

Silver recovery methods such as those described in Chapter 7 should be used.

Treatment

IW/PW - Treatment/Better Operating Practices - Incineration

Incineration is one of the options used to treat infectious wastes. The manufacturer's operating instructions and standard operating procedures must be posted on the incinerator. A State or local air quality permit must be obtained and the incinerator must be operated in compliance by following the manufacturer's recommended temperature to reduce emissions and opacity problems.

The incinerator ash could be a hazardous waste. It should be tested annually for hazardous characteristics. Testing of incinerator ash at Army installations has revealed that it is Extraction Procedure (EP) toxic for heavy metals.[126]

---

[124] National Research Council, pp 44-55.

[125] National Research Council, Chapter 4.

[126] *Protocol Health Care Facility Waste Management Surveys.*

The red bags used to contain IW/PW burned in incinerators are made of chlorinated plastics (PVC). Burning these red bag wastes generates a number of air pollutants of concern including hydrochloric acid, dioxins, furans, and particles. These toxic stack emissions are a significant hazard to the community. As public concern increases (and regulations change) proper flue-gas cleanup will be required. Some of the air emission control devices that could be installed include dry impingement separators, dry cyclonic separators, venturi scrubbers, electrostatic precipitators, fabric filters, wet acid gas scrubbing devices, and dry scrubbing systems.

IW/PW - Treatment/Better Operating Practices - Autoclaves/Retorts

Autoclaves or retorts are used in several hospitals to disinfect IW/PW before landfill disposal. All the operators should be trained in proper equipment use. The bags used in autoclaves should allow sufficient steam penetration and yet contain the wastes. Compaction of wastes must always follow the autoclaving process. Spore strips should be used to check the effectiveness of the operation.

HW (solvents) - Onsite Treatment - Incineration

If recovery by distillation is not a feasible option, onsite incineration should be considered. A permit is needed to operate an incinerator to burn solvents. Therefore, onsite incineration may not be a practical option for most Army hospitals. However, with the increase in offsite incineration costs and the ban on land disposal of liquid wastes and long-term liabilities, onsite incineration may become a feasible treatment method in the future.

Waste designated for incineration must have a high Btu content, a high flash point, low specific gravity, and a low solids content. The incinerator must be designed to achieve complete destruction while generating negligible quantities of air pollutants. Both technical and institutional problems have to be addressed before acquiring an incinerator to burn small amounts of a wide variety of chemical wastes.[127]

HW (solvents) - Offsite Treatment - Incineration

Use of offsite facilities to incinerate solvent wastes may be a feasible option for most laboratories. Commercial incineration facilities require generators to segregate wastes and arrange for transportation.

[127] National Research Council, Chapter 9, pp 111-125.

LW (acids/alkalis) - Treatment - Neutralization

Elementary neutralization of corrosive liquids is exempt from treatment permit requirements. Acids (pH < 2) and alkalis (pH > 12.5) must be neutralized before they are allowed to flow into the drain.

9 Waste Minimization for Other Source Types

Heating and Cooling Plants

Army installations have a number of heating and cooling plants that generate power and steam. Hazardous wastes are generated by using various combustible chemicals (e.g., cyclohexylamine) and corrosive chemicals (e.g., caustic soda, caustic potash, hydrochloric acid) to adjust pH, prevent scaling or corrosion, clean the interior of the boiler, and to test feedwater. In addition, boiler blowdown liquid mixed with water is a hazardous waste generated periodically. Waste oil blended with virgin fuel oil is burned in boilers at some installations. The waste oil may be a hazardous waste, depending on the content, and should be burned only in permitted facilities.

A number of efficiency-related boiler maintenance procedures can be used to minimize environmental pollution while correcting malfunctions in boiler operation and preventing performance degradation. Component malfunction or performance degradation can cause increases in stack gas temperature; excess air requirements; carbon monoxide, smoke, or unburned carbon in ash; convection or radiation losses from the boiler exterior, ductwork, and piping; blowdown above that required to maintain permissible water concentrations; and auxiliary power consumption by fans, pumps, or pulverizers. In addition to the normal maintenance recommended by manufacturers, efficiency-related maintenance procedures must be performed to extend equipment life and for personnel safety. These procedures include efficiency spotchecks of combustion conditions, establishing best achievable performance goals, monitoring performance (boiler log) to document deviations, periodic equipment inspection, and troubleshooting.[128] Boiler tuneups also improve efficiency and fuel conservation.

Some modifications to the boiler operating practices improve boiler efficiency, save fuel, and reduce continuous blowdowns. These practices include reducing boiler steam pressures, controlling the water quality by continuous blowdowns instead of infrequent blowdowns, and proper load management. Efficient boiler operation also minimizes the amounts of air pollutants (particulates, carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons, and oxidants) released to the atmosphere.

---

[128] *Efficient Boiler Operations Sourcebook*, F.W. Payne, Ed. (The Fairmont Press, Inc., Atlanta, GA, 1986), pp 79-106.

Managing the chemical inventory and reducing chemical use in water treatment and scale removal minimizes the amounts of wastes produced. Nonhazardous substitutes should be developed and used instead of the combustible and corrosive chemicals normally found at heating and cooling plants.

Laundry and Drycleaning Facilities

Laundry and drycleaning facilities on an Army installation are the responsibility of the DOL. Caustic soda and other corrosive chemicals are used in the laundry. Perchloroethylene (PERC) is the most common drycleaning solvent used. The two other solvents commonly used are Valclene™ (fluorocarbon 113 or tetrachloroethylene), and petroleum distillates (Stoddard). Use of solvents and corrosive chemicals in these processes results in the generation of contaminated wastewater and dry wastes (Table 22).

PERC drycleaning plants generate several waste streams: (1) still residues from solvent distillation (entire weight), (2) spent filter cartridges (total weight of cartridge and solvent remaining after draining), and (3) cooked filter residue (the total weight of drained powder residue from diatomaceous or other powder filter systems after heating to remove excess solvent). Valclene plants generate still residues and spent filter cartridges. Stoddard solvent plants generate still residues only. Proper disposal is required for all hazardous wastes generated at laundry and drycleaning facilities. Among the acceptable options are recycling, incineration, or disposal in an authorized hazardous waste landfill. However, source reduction by material substitution seems to be the most effective minimization technique for drycleaning operations. The possibility of replacing PERC or Valclene with Stoddard (PD680-II) or petroleum naphtha must be explored. Table 22 shows that using Stoddard produces the smallest quantity of hazardous waste. If the petroleum solvent has a flash point greater than 140 °F, the wastes are not considered hazardous and are exempt from reporting requirements. Drycleaning plants generally have stills for continuous distillation of solvents. However, the still bottoms must be disposed of properly.

Woodworking and Preserving

Table 23 lists typical woodworking and preserving operations and corresponding hazardous materials used. Some of the wastes are generated by carpentry shops that manufacture or refinish wooden cabinets, softwood and hardwood veneer and plywood, household or office furniture, and other furniture (including reupholstery and repair). Typical wood preserving operations used to condition wood include steaming, boultonizing, kiln or air drying (under pressure or vacuum), and applying agents such as creosote, pentachlorophenol (PCP), and other arsenical compounds.

Inventory control and management is an effective technique for minimizing hazardous wastes associated with woodworking and preserving. Proper disposal practices should also be used.

Pesticide Users

Army installations have a number of pesticide users including the entomology shop (pest control services), the garden shop (lawn, garden, and tree services), and the golf courses. Use of pesticides in activities ranging from protecting food and structures to pest and disease control results in generation of hazardous rinsewater, empty containers with pesticide residue, unused pesticides, and possibly contaminated soil.

Very dilute rinsewaters or soil contaminated with very low concentrations may not be hazardous. Chemical analysis is necessary to verify the concentrations. Pesticide containers are not a hazardous waste if they are triple rinsed. The rinsewater, however, is a hazardous waste. Some pesticides that contain flammable solvents or ignitable material are also hazardous wastes when discarded. A number of pesticides exhibit acute toxicity characteristics. All discarded and off-specification products, containers, and spill residues containing acute toxic components are listed as "P" hazardous wastes [40 CFR 261.33(e)]. All the hazardous material/wastes related to pesticides must be managed carefully to prevent environmental problems and to protect the health and safety of personnel.

Pesticides should be purchased on an as-needed basis. Proper inventory control will reduce the quantity of unused pesticides that are disposed of. Generation of pesticide rinsewater can be minimized by using multiple rinse tanks, installing drain boards and drip tanks, and recycling and reusing the water for rinsing.[129] Treatment methods include destruction with chlorine or lime, incineration, and carbon adsorption.[130] Minimization and disposal of empty containers and contaminated soil wastes will be discussed in Chapter 10.

---

129 Ventura County Environmental Health, *Hazardous Waste Reduction Guidelines for Environmental Health Programs* (California Department of Health Services, Sacramento, CA, 1987).

130 *Standard Handbook of Hazardous Waste Treatment and Disposal,* H.M. Freeman, Ed. (McGraw Hill, New York, NY, 1989).

Open Burning/Open Detonation

Open burning/open detonation (OB/OD) is one option used to demilitarize ordnance containing propellants, explosives, and pyrotechnics (PEP). Other methods are washout/steamout/meltout and deactivation in a furnace. OB/OD is the simplest and has been the primary method of demilitarization used at Army installations.[131] Active and inactive sites of OB/OD are commonly found. The environmental contaminants generated from OB/OD activity include gases and particles (carbon, soot, etc.) released into the atmosphere and as residues in soils. The soil residues are comprised mainly of undetonated PEP materials and combustion/detonation products. Soils at all the active and inactive sites must be analyzed to determine the chemical content and proper disposal actions.

Some of the materials in the demilitarization inventories at installations may have a recovery value in excess of the cost of the original item because of the increase in material and manufacturing costs.[132] Recovery and reuse of such materials before burning will reduce raw material costs and production requirements, and minimize wastes generated. A number of processes (e.g., resolvation of ground propellants, selective solvent extraction, disposal of scrap propellant, solution-pelletization, etc.) are available for recovery and reuse of propellants or their ingredients. Processing propellants by such reclamation techniques minimizes environmental discharges, conserves strategic materials, and provides cost savings.[133]

Under USEPA and State regulations, OB/OD is considered a treatment technique for hazardous wastes (ordnance). Therefore, installations are required to obtain a Part B permit. The generation of contaminated soil residues from OB/OD activity can be minimized by conducting the activity on steel "burn-pans" instead of on open ground. Incineration must also be explored as a possible minimization alternative. Controlled incineration allows for better control of air pollutants. Proper disposal is required for residues generated in any of the operations.

---

131 D.W. Layton, et al., *Demilitarization of Conventional Ordnance: Priorities of Data-Base Assessments of Environmental Contaminants*, UCRL-15902 (U.S. Army Medical Research and Development Command [USAMRDC], Fort Detrick, MD, 1986).

132 D.W. Layton, et al.

133 F.W. Nester and L.L. Smith, *Propellant Reuse Technology Assessment*, AMXTH-TE-CR-86076 (USATHAMA, Aberdeen Proving Ground, MD, 1986).

Firefighting and Training

Aqueous film forming foam (AFFF) is considered a hazardous material in a number of states. Firefighting operations that use AFFF should replace it with nonhazardous substitutes. All other wastes generated by maintenance of fire trucks and other equipment can be minimized by methods discussed in Chapters 4 and 5.

Another waste generated from fire training activities is contaminated soils in the training pits. Typically, contaminated fuel (e.g., JP-4, gasoline) is used to generate a fire in the pits for training exercises. The soil from the pits must be analyzed for chemical contaminants and properly disposed of.

Underground Storage Tanks (USTs)

Discovery of a number of leaking USTs throughout the United States prompted Congress to add Subtitle I to RCRA in 1984. Subtitle I requires the USEPA to develop regulations for leaking USTs to safeguard human health and the environment. In September 1988, USEPA finalized the UST rules and regulations that cover the technical requirements for designing, installing, testing, and monitoring USTs, and the requirements for cleanup following releases from leaking USTs.[134] Many USTs are located on each Army installation. They should all be tested for leaks and any leaking tanks must be managed according to the UST regulations. Proper management of USTs will minimize the quantities of vapor emissions, soil contamination, and potential groundwater contamination.

A data base of information on Army-owned USTs was developed at USACERL.[135] Many of the Army's USTs are more than 30 years old, have capacities of over 10,000 gal, may contain hazardous substances, are made of steel, and have a high potential for leakage. A leak potential index (LPI) associated with the data base has been devised to indicate the likelihood of individual tank leakage.[136] The LPI enables tank managers to group tanks based on the likelihood of leaks. This information indicates which tanks should be monitored more closely, which should be tested, and which should be considered for replacement.

---

[134] 40 CFR Parts 280-281, *Underground Storage Tanks: Technical Requirements and State Program Approval; Final Rule,* pp 37081 - 37247.

[135] B.A. Donahue, T.J. Hoctor, and K. Piskin, *Managing Underground Storage Tank Data Using dBase III Plus*, Technical Report N-87/21/ADA182452 (USACERL, June 1987).

[136] S. Dharmavaram, et al., "A Profile and Management of the U.S. Army's Underground Storage Tanks," *Environmental Management*, Vol 13 (1989), pp 333-338.

The HAZMIN technique of inventory control is very effective in detecting tank leaks. This method requires regular measurement of the level of substances in the tanks. Records must also be maintained concerning addition and withdrawal of products. Comparison of inflow, outflow, and the inventory indicates product loss. Other leak detection methods can be grouped into volumetric methods, nonvolumetric methods, and leak effects monitoring.[137] Volumetric methods measure the change in volume with time and are the most fully developed and popular. Site-specific decisions have to be made regarding the use of the most appropriate leak detection method. Nonvolumetric methods measure changes in a variable, such as a tracer gas or acoustic signal, to determine changes in the level of the tank contents. Leak effects monitoring refers to methods used to determine leaks in the surrounding environment (e.g., soil vapor analysis).

---

137 J. Makwinski and P.N. Cheremisinoff, "Special Report: Underground Storage Tanks," *Pollution Engineering*, Vol 20 (1988), pp 60-69.

Table 22. Amounts of typical hazardous wastes generated from drycleaning operations.*

	Cleaning Solvent (lbs/1000 lbs clothes cleaned)		
Waste Type	PERC	Valclene	Stoddard
Still Residues	25	10	20
Spent Cartridge Filters			
Standard (carbon core)	20	15	**
Adsorptive (split)	30	20	**
Cooked Powder Residue	40	n/a	n/a
Drained Filter Muck	n/a	n/a	**

* Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986), p 144.

** Well-drained filter cartridges and filter muck are solids that do not meet the criteria for classification as an ignitable solid, and are therefore not considered hazardous wastes.

Table 23. Wastes classification: woodworking and preserving operations.*

Process/Operation	Materials Used	HW Code
Wood cleaning and wax removal	Petroleum distillates	D001
	White spirits	D001
Refinishing/ stripping; brush cleaning and spray gun cleaning	Paint strippers (containing methylene chloride)	F002
	Paint removers (containing distillates, acetone, toluene)	D001
	Paint removers (containing caustic)	D002
Staining	Stains (mineral spirits, alcohols, pigments)	D001
Painting	Paints (enamels, lacquers, epoxy, alkyds, acrylics)	D001
Finishing	Varnish, shellac, lacquer	D001
Preserving	Creosote	K001
	Pentachlorophenol	K001
	Chromated copper arsenate	D004/D007
	Ammoniacal copper arsenate	D004
	Other wood preservatives	Varies

* Source: H. Winslow, *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986), pp 146-147.

10 Waste Minimization for Miscellaneous Wastes

Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are chlorinated organic compounds with a wide range of physical properties. There are 209 possible PCBs of which tri-, tetra-, penta-, and hexachloro biphenyls are the most important. They were commonly used in coolants and insulation fluids in transformers. Some of the older products that may contain PCBs or oils with PCBs include heat-transfer fluids, lubricants, paints, plastics, air conditioners, fluorescent lights, and televisions. PCBs were most widely used in capacitors and transformers because of their low conductivity and thermal stability.

In several cases of poisoning in Japan and Taiwan, PCBs and their secondary products such as polychlorinated dibenzofurans were found to be the major contaminants in bran oil used to cook rice. Since then, PCBs have been linked to severe health problems (e.g., gastric disorders, skin lesions, swollen limbs, cancers, tumors, eye problems, liver disorders, menstrual irregularities, etc.) and birth defects (e.g., reproductive failures, mutations, etc.). Compounding the problem of PCBs' toxicity is their bioaccumulation in cells and fatty tissues of micro-organisms and animals, which are then consumed by other animals higher in the food chain.

PCBs are regulated by the Toxic Substances Control Act (TSCA) passed in 1976. Manufacture of PCBs was banned under TSCA and deadlines were provided for removing capacitors and transformers containing PCBs. One year was allowed for storage before disposal. If regulatory agencies determine that the use of PCB transformers poses no risk, the use will be allowed to continue. All capacitors were to have been removed by October 1988, and transformers of certain size in or near commercial buildings should have been removed by October 1990.

If the concentration of PCBs in a product is greater than 50 parts per million (ppm), the product is regulated as hazardous under TSCA. Some States have set limits that are stricter than Federal limits (e.g., the California limit is 5 ppm). PCBs should also be tested for hazardous characteristics under RCRA.

PCBs in Transformers

In the United States, there are 150,000 askarel (nonflammable electrical fluid) transformers, each of which contains thousands of pounds of PCBs with a wide range of concentrations.[138] Many of these transformers develop leaks.

Transformers are generally classified as PCB transformers (greater than 500 ppm), PCB-contaminated transformers (50 to 500 ppm), and non-PCB transformers (less than 50 ppm). PCB transformers must be inspected quarterly for leaks, and detailed inspection records must be kept. No maintenance work involving removal of the coil or casing is allowed. PCB-contaminated transformers must be inspected annually. The requirements for maintenance and recordkeeping are less restrictive than for PCB transformers. Non-PCB transformers are exempt from regulation.

The importance of analyzing all transformers for PCBs must be stressed. All the transformers on an installation must be inventoried and tested for PCBs. If the PCB levels are greater than 50 ppm, appropriate actions must be taken.

PCB Wastes Management

There are no minimization options available for PCB wastes. Recycling of PCBs is illegal. Nevertheless, containers and oils contaminated with PCBs may be recycled if the PCBs are removed.

Federal regulations require that PCBs be destroyed in approved high-temperature incinerators. Oils containing 50 to 500 ppm PCBs can be burned in high-efficiency boilers. Alternate technologies capable of operating at the high incinerator efficiencies, such as the molten salt processes or UV/ozonation may also be considered for "ultimate" treatment/disposal. In addition to incineration, which is the most common, chemical dechlorination technologies have also been successful. Table 24 lists the names and addresses of incineration facilities and available chemical dechlorination services.

The most common practice at Army installations is to retain PCB transformers in service until they leak or reach the end of their useful life. They are then replaced with non-PCB transformers. The other possible options that may be available are decontaminating and/or retrofilling the transformers. Table 25 lists the names and addresses of companies that provide retrofilling services.

---

[138] P.N. Cheremisinoff, "High Hazard Pollutants: Asbestos, PCBs, Dioxins, Biomedical Wastes," *Pollution Engineering*, Vol 21 (1989), pp 58-65.

USACERL's PCB Transformer System

A computer-aided, fate-decision analysis tool was developed at USACERL to help users make decisions about transformers containing PCB levels greater than 50 ppm. The computer model is available to Army users through the Environmental Technical Information System (ETIS) on the mainframe computer at USACERL.[139] A PC-based model is also available.[140]

The model provides users with information about PCBs and appropriate regulations, and allows them to input information for risk assessment, fate-decision analysis, and life cycle cost analysis. The options considered in the final economic analysis are retaining, retrofilling, decontaminating, and replacing transformers.

Onsite Mobile Treatment Units

Mobile incineration and chemical dechlorination units can decontaminate insulating oils from transformers. One dechlorination process, the "PCBX" process developed by ENSR (formerly SunOhio), is a self-contained continuous-flow unit. It is designed and equipped to destroy PCBs (up to 2600 ppm) from transformer oil without moving the transformer. The operating capacity of the unit is up to 600 gallons per hour. Exceltech, Inc., based in California, also markets mobile dechlorination units for removing PCBs from transformers.

Lithium Batteries

Lithium batteries are discarded from troop equipment that uses batteries as a reserve power source. Six types of primary lithium batteries are commonly used: Li-CuO, Li-nnO2, Li-(CFx)n, Lithium Sulfur dioxide (Li-SO2), Li-SO2C12, and Lithium thionyl chloride (Li-SOC12).

The U.S. Navy has proposed the development of a center of excellence to develop a fully permitted state-of-the-art, portable disposal technology for world-wide utilization.[141] A study conducted by USAEHA to evaluate the disposal of lithium batteries under RCRA regulations noted that fully charged and duty-cycle discharge batteries were hazardous because of reactivity and/or ignitability characteristics and must be

---

[139] Reinbold, K., M.A. Curvey, and P.T. Conroy, *PCB Transformer System User Manual: ETIS Version 2.0*, Automaitc Data Processing (ADP) Report EP-93/03/Unpublished (USACERL, February 1993).

[140] Reinbold, K., M.A. Curvey, and P.T. Conroy, *PCB Transformer User Manual: PC Version*, ADP Report EP-93/02/ADA269192 (USACERL, February 1993).

[141] Comarco, Inc., *U.S. Navy Lithium Battery Disposal*, Report No. CESD-88-179 (Prepared for the Naval Weapons Support Center, High Energy Battery Systems Branch, Crane, IN, January 1989).

discharged through the DRMO.[142] Fully discharged batteries are not hazardous and could be disposed of in a permitted landfill. Assurances must be sought that the batteries have reached their fully discharged state. Manual discharging methods such as soaking in an aqueous solution are not practical and alternative approaches must be explored.

A recent review presents general information regarding lithium batteries.[143] It includes information about battery technology, safety aspects, purchasing, packaging, transport, storage, and disposal.

Ordnance

A number of hazardous ordnance materials are used on Army installations. Details on materials used in ordnance are available in Technical Manual (TM) 9-1300-214.[144] Army directives prohibit burial of ordnance materials or dumping them in waste places, pits, wells, marshes, shallow streams, rivers, inland waterways, or at sea. All existing locations of buried explosives must be identified and marked accordingly. The only means of ultimate disposal currently available is destruction by burning and detonation (discussed in Chapter 9). Proper operating procedures for disposal of discarded ordnance materials should be developed and updated frequently to comply with Federal, State, and local regulations.

Contaminated Soil

Soil contaminated by leaking or spilled hazardous materials must be disposed of as hazardous waste. Some effective source reduction techniques include installing splash guards and dry boards on equipment, preventing tank overflow, using bellow sealed valves, installing spill basins, using seal-less pumps, installing secondary containment, keeping up with required plant maintenance, and providing personnel training to develop good operating practices.

A number of nonthermal and thermal treatment techniques are available for decontamination of soil. Nonthermal techniques include aeration, biodegradation, carbon adsorption, chemical dechlorination, solvent extraction, stabilization/fixation,

---

[142] *Evaluation of Lithium Sulfur Dioxide Batteries, US Army Communications - Electronics Command and US Electronics Research and Development Command, Fort Monmouth, New Jersey*, USAEHA-37-26-0427-85 (USAEHA, Aberdeen Proving Ground, MD, 1985).

[143] W.N. Garrard, *Introduction to Lithium Batteries*, MRL-GD-0018; DODA-AR-005-652 (Materials Research Laboratory, Ascot Vale, Australia, 1988).

[144] Technical Manual (TM) 9-1300-214, *Military Explosives* (Headquarters, Department of the Army, 20 September 1984).

and ultraviolet photolysis. Thermal treatment techniques include stationary rotary-kiln incineration, mobile rotary-kiln incineration, liquid injection incineration, fluidized bed incineration, high-temperature fluid-wall destruction, infrared incineration, supercritical-water oxidation, plasma-arc pyrolysis, and in situ vitrification.[145]

Empty Containers

Containers with residual hazardous materials/wastes must also be treated as hazardous wastes. Under HSWA, if a container with hazardous residue is found in a cleanup (Superfund) site or other landfill, the generator (Army) is liable and has to pay for part of the cost of cleanup. Even triple rinsed containers could contain some residue. Scrap dealers and landfills are becoming reluctant to accept "clean" empty 55-gal drums or other containers.

The problem of disposing of empty drums and containers can be minimized by giving careful consideration to the kinds and sizes of containers in which materials are originally received. When purchasing materials in bulk, the suppliers should be required to send them in rinsable and/or recyclable containers. A number of commercial recyclers (listed in Regional Waste Exchange bulletins/newsletters or directories) accept containers less than 30 gal.[146] Treating empty containers by triple rinsing is a good waste minimization technique. However, the rinsate, if hazardous, must be properly managed.

Some of the other options to consider when procuring materials, and in the ultimate disposal of containers, are returning drums to suppliers, contracting with a drum conditioner, contracting with a scrap dealer, and, lastly, disposal in an approved landfill.[147]

Returning Drums to Suppliers

When buying material, a purchase agreement should be established to include the option of returning empty containers to the suppliers. Cash deposits may be required and drums should be maintained in good condition. All the accessories, such as bungs, rings, and closures, must also be kept and returned with the drums.

---

145 *Standard Handbook of Hazardous Waste Treatment and Disposal.*

146 Ventura County Environmental Health, p 3-2.

147 *Managing Empty Containers*, Fact Sheet (Minnesota Technical Assistance Program, University of Minnesota, Minneapolis, MN, 1988).

Contracting With a Reconditioner

If the suppliers do not sell chemicals in returnable drums, ask them to send materials in heavy steel (18 to 20 gauge) drums that can be reconditioned when empty. A typical 55-gal heavy drum should have a 20-gauge side and 18-gauge ends. A good market exists for these drums and they can be sent to reconditioning contractors for minimal or no cost. Empty heavy drums must be treated as a valuable asset and personnel should be trained in their proper handling (including keeping the bungs, rings, etc.). Another good practice is to avoid accumulating the drums for long periods of time, thus, preventing deterioration.

Contracting With a Scrap Dealer or Disposal in a Landfill

Scrap dealers and landfill operators usually require certain conditions to be met before they accept drums or other containers. Generators have to drain the drums or containers thoroughly, remove the residues by triple rinsing, certify that they do not contain hazardous materials, remove both the ends, crush them before transporting, and pay for disposal.

Table 24. PCB replacement/treatment diposal services.

Company	Address
ENSCO	P.O. Box 1975, El Dorado, AR 71730, (501) 863-7173
ENSR (formerly SunOhio)	1700 Gateway Blvd. SE, Canton, OH 44707, (216) 452-0837
USEPA Mobile Incinerator	Woodbridge Ave., Raritan Depot Bldg. 10, Edison, NJ 08837, (201) 321-6635
GSX Chemical Services	121 Executive Center Dr., Congaree Bldg. # 100, Columbia, SC 29221, (800) 845-1019
Rollins	P.O. Box 609, Deer Park, TX 77536, (713) 479-6001
General Electric	One River Road/Bldg 2-111B, Schenectady, NY 12345, (518) 385-9763
SCA Chemical Services	1000 E. 111th St., 10th Fl., Chicago, IL 60628, (312) 660-7200

Table 25. PCB transformer retrofilling services.

Company	Address
DOW Corning Corp	P.O. Box 0994, Midland, MI 48686-0994, (517) 496-4000
ENSR (formerly SunOhio)	1700 Gateway Blvd. SE, Canton, OH 44707, (216) 452-0837
General Electric	One River Road/Bldg 2-111B, Schenectady, NY 12345, (518) 385-9763
Hoyt Corporation	251 Forge Rd., Westport, MA 02790-0217, (800) 343-9411
Retrotex	1700 Gateway Blvd. SE, Canton, OH 44707, (216) 453-4677
Transformer Service Inc.	78 Regional Dr., P.O. Box 1077, Concord, NH 03301-9990, (603) 224-4006
Unison Transformer Services	1338 Hundred Oaks Dr., Charlotte, NC 28210, (800) 544-0030
Westinghouse/Industry Services	875 Greentree #8-MS 804, Pittsburgh, PA 15220, (800) 441-3134

11 Economic Analysis for Hazardous Waste Minimization

HSWA requires generators of hazardous wastes to develop a waste minimization program that is economically practicable. Therefore, once the alternatives for minimization are identified, their economic feasibility must also be studied. A major source for funding for hazardous waste minimization projects has been through the Defense Environmental Restoration Account (DERA). If the payback from a project is expected to be 1 year or less, funding is also available from the Defense Productivity Enhancing Capital Investment (PECI) program. In many instances, minimization is a cost-effective means of conducting business. In such instances, any account may be used to finance minimization and benefit from the resultant savings. However, with the multiplicity of alternative treatment technologies available to treat various hazardous waste streams, it is imperative that installation environmental personnel use a standard methodology to evaluate hazardous waste minimization options.

In 1984, DOD initiated a Used Solvent Elimination (USE) program. In conjunction with the USE program, USACERL developed a model for performing an economic analysis on various alternatives for recycling or disposing of used solvents. Based on this earlier model, a microcomputer model has been developed for economic analysis of hazardous waste minimization options.[148,149] This model was used to determine the life cycle costs and comparison of alternatives for waste streams in this report.

Determining an economically practicable level of waste minimization, as defined in HSWA, is very important. It is not necessary (and is impossible in most cases) to completely eliminate generation of wastes. An economic analysis provides a reasonable method for choosing between options for waste minimization. The typical costs considered for any option are initial capital costs and operating costs such as labor, materials, transportation, and waste disposal. Benefits achieved from a waste minimization option (e.g., reduced liability) can also be quantified and given dollar values.

---

[148] S. Dharmavaram, J.B. Mount, and B. Donahue, "Automated Economic Analysis Model for Hazardous Waste Minimization," *J. Air Waste Manage. Assoc.*, Vol 40 (1990), pp. 1004-1011.

[149] K. Chylla and G. Zipfel, *Economic Analysis for Minimizing Hazardous Wastes, Version 2.1: User's Manual,* ADP Report N-90/07/ADA219670 (USACERL, March 1990).

The costs are summed to obtain life cycle costs over the assumed economic life for each option. Net present value (NPV) of the total life cycle costs can be calculated for each option. Comparing the NPVs provides a basis for selecting a minimization technique. Results of detailed economic analysis for the selected waste streams are provided in the sections below.

Used Oil

A large quantity of used oil, primarily engine lubricating oil, is generated on Army installations. Fort Riley generates approximately 130,000 gal/yr of used oil. Lubricating oil is drained from wheeled and tracked vehicles by the traditional drip-pan method and collected in 55-gal drums or larger storage tanks. If proper segregation practices are not followed, the used oil can become contaminated with trash, rags, solvents, hydraulic fluids, or antifreeze. Contamination makes the oil much more difficult to dispose of.

The two options considered for management of used oil are offsite recycling by re-refining the used oil, and the current practice of offsite recycling by blending the oil with fuel and burning the mixture in an industrial boiler. In both options, the contractors will send a truck and driver to remove waste oil from Fort Riley's underground storage tanks. Proper segregation of used oil from other wastes generated on Fort Riley is a prerequisite for both management options analyzed.

In FY91 Fort Riley paid $.28/gal to Central Kansas Crude, Iuka, KS for removal of the used motor oil. The oil was transported to the contractor's boiler for blending and burning. This option is somewhat undesirable because environmental groups and Congress have recently questioned whether burning used oil should be considered recycling.

In FY92, a new contract with Midwestern Oil was initiated. The used motor oil is being recycled under this contract. Fort Riley still pays for the disposal. In FY92 the contract was for $.176/gal, while in FY93 the cost increased to $.195/gal.

Safety Kleen, Inc., can also provide oil removal service. SK owns and operates several oil re-refineries. SK will also assume responsibility for proper disposal of the used oil after they take it. This would significantly reduce Fort Riley's potential liability in case a spill or other contamination occurs. SK was unable to provide price information for the used oil service or to guarantee that the oil recycling service would be available at Fort Riley. Fort Riley should work with their local SK office to set up a contract to re-refine their used oil. This may or may not be more cost-effective than the current contract, but it is certainly the more environmentally sound option.

Antifreeze Solution

MPVMs are the primary generators of waste antifreeze solution during regular maintenance of vehicles and major radiator repairs. Antifreeze is considered a controlled waste and is disposed of as such through DRMO. Recycling of the waste solution is possible as discussed in Chapter 4. It was considered as a minimization alternative and the results of the economic analysis are presented below.

Investment costs for the antifreeze recycling machine are assumed to be incurred in the first year. A 10-yr economic life and midyear discounting at a rate of 10 percent are assumed for the options. The model's default values used in this analysis include the following.

- Site preparation and installation - 15 percent of total equipment costs,
- Logistics and procurement - 7 percent of installed equipment costs,
- Contingencies - 10 percent of installed equipment costs,
- Labor rate (manager) - $16.00/hr,
- Labor rate (laborer) - $11.00/hr,
- Adjustments for leave - 18 percent of total labor hours,
- Adjustments for fringe benefits - 36.2 percent of adjusted base labor cost,
- Number of work days in a year - 247,
- Average maintenance - 5 percent of equipment costs,
- Transportation of hazardous waste - $0.04/lb, and
- Annual logistics and procurement - 1.6 percent of other O&M costs.

Some of the assumptions made in the economic analysis are:

- Disposal cost of antifreeze is $1.25/lb,
- Labor hours for manager (bids, etc.) - 1 hr/667 gal; and laborers (drumming and transport) - 1 hr/66.7 gal,
- Cost of Glyclean recycling system is $3500,
- The Glyclean filter cost is $.115/gal,
- The cost of a 55-gal drum of Glyclean additives is $21/gal; about 0.02 gal of additive is needed per 1 gal of antifreeze recycled,
- It takes about 1 hr to recycle 100 gal of used antifreeze,
- The purchase price of new antifreeze is approximately $4 per gallon,
- Recycled antifreeze is equivalent to a 50 percent mixture of antifreeze and water,

- The density of the antifreeze/water solution is approximately 8.8 lbs/gal,
- Utility costs associated with Glyclean machine operation is $0.02/gal of waste,
- Repair and maintenance cost is $0.006/gal,
- The liability cost for both disposal and reuse is $0.01/gal, and
- Onsite transport cost from point of waste generation to recycling facility and back or to DRMO for disposal is $2.00/100 gal.

Fort Riley generates approximately 29,500 lb/yr of spent antifreeze solution. Two management options were considered: offsite disposal (current option), and onsite recycling and reuse with one Glyclean recycling system. The current option costs approximately $44,276/yr based on the assumptions listed above.

The Glyclean recycling unit filters and revitalizes antifreeze. Antifreeze is poured or siphoned into the unit, and the filtering process is done automatically. An additive is then mixed with the ethylene glycol to restore alkalinity. Corrosion inhibitors are added to improve inhibition properties beyond those of the original liquid. The process can be repeated indefinitely.

Purchasing a recycling system would require a NPV investment of $4,491. The NPV savings over the 10-year economic life would be $243,488 (or $24,349/yr). The Savings to Investment Ratio (SIR) and Discounted Payback Period (DPP) for the recycling option with respect to the current option are estimated at 54.20 and 1.13 years, respectively. The purchase of a Glyclean reconditioning system and the implementation of an onsite recycling program for spent antifreeze is recommended.

Cleaning Solvent Waste

Cleaning solvents such as petroleum distillates (PD680), petroleum naphtha, varsol, etc., are used in parts cleaning operations as discussed in Chapter 4. At Fort Riley, the majority of solvent used is petroleum distillates provided under a service and recycling contract with Safety Kleen. SK leases parts cleaning equipment and replaces the solvent periodically. Fort Riley uses 36,815 gallons of parts cleaning solvent in a year. Building 8100 accounts for about 9,900 gal/yr of this total. SK estimates that approximately 30 percent of the solvents are lost to drag-out and evaporation, leaving approximately 23,561 gal/yr of waste solvent to be recycled at Fort Riley.

Four management options were chosen for economic analysis: (1) contractor recycling (current option); (2) onsite recycling (via a distillation unit) in building 8100 only, with the SK contract continued for the rest of the installation; (3) onsite recycling (via a centralized still) for all of Fort Riley; (4) onsite recycling with two stills, one for building 8100, and one for the rest of Fort Riley. Investment costs required for distillation equipment and a startup volume of fresh solvent in options 2, 3 and 4 are assumed to be incurred in the first year. A 10-yr economic life and a midyear discounting at a rate of 10 percent are assumed for all the options. The model's default values used in this analysis include

- Logistics and procurement - 7 percent of installed equipment costs,
- Contingencies - 10 percent of installed equipment costs,
- Labor rate (manager) - $16.00/hr,
- Labor rate (laborer) - $11.00/hr,
- Adjustments for leave - 18 percent of total labor hours,
- Adjustments for fringe benefits - 36.2 percent of adjusted base labor cost,
- Number of work days in a year - 247,
- Average maintenance - 5 percent of equipment costs,
- Transportation of spent solvent - $0.04/lb, and
- Annual logistics and procurement - 1.6 percent of other O&M costs.

Some of the other major assumptions used in the calculations are listed below.

- Liability costs for onsite distillation and reuse - $0.07/gal.
- Liability costs for offsite disposal/sale - $0.03/gal.
- Twenty percent of the solvents are assumed lost to evaporation due to failure to lower parts washing station lids, and other poor operating practices such as drag-out and spillage.
- Volume of the still bottoms is assumed to be 7.5 percent of the total waste stream.
- Fresh solvent will need to be purchased every year. It is expected to be 36 percent of the volume used annually.
- Repair and maintenance costs are calculated to be 5 percent of the original cost of the equipment (in $/year) and are based on 2500 hours of operation per year.
- The still can operate unattended and will shut down automatically when the batch is completed. This will allow the still to be operated for more than 8 hr/day.
- Laboratory analytical costs are assumed to be 3 percent of direct labor costs.
- Transporting and warehousing costs are based on the volume of wastes generated; about $.80/100 gal.
- The cost of electricity is $0.05 per kWh.
- The cost of disposal of still bottoms (assumed hazardous) is $2.70/lb.
- The cost of new solvent (PD680-I - flash point 105 °F, boiling point 310 to 400 °F) is $1.29/gal.
- Because the boiling point of solvent is above 300 °F, a vacuum attachment must be used in the distillation process.

- Labor for loading and unloading the still will be less than 2 hr/batch.
- The utility costs are about $0.04/gal of solvent distilled.
- Labor associated with the transport of spent solvent to the distillation site is 1 hr/100 gal.
- The still prices listed in Table 17 were used in the analysis. Distillation units from Finish Engineering, Solvent Recovery Systems, PBR Industries, Solvent Kleene, and Progressive Recovery Inc. were considered for the analysis. Shipping costs for equipment are not included in the prices listed in Table 17.

SK is a solvent leasing and recycling contractor that currently holds the service contract with Fort Riley (option 1). Most of the vehicle maintenance facilities on Fort Riley have been equipped with parts-washing equipment leased from SK. Of the 263 parts washing units located at Fort Riley, SK owns 163, and Fort Riley owns 100. Unlike most of the MPVMs, only a few of the parts washing units in Building 8100 are owned by SK, with 37 government-owned sinks and only 8 SK-owned sinks. The cleaning equipment varies in style and capacity from 5-gallon, multi-level units up to 40-gallon stationary tanks that require special installation. Each unit is serviced every 4 to 12 weeks by SK and replenished with clean, recycled solvent. The solvent supplied by the vendor is roughly equivalent to PD680-I in flash point and chemical composition. SK assumes the responsibility for spent solvent containerization, transport to the recycling facility, and disposal of solvent tank bottoms. The spent solvent and tank bottoms are manifested as hazardous waste based on the flashpoint of the fresh solvent (105 °F). The annual operating costs of the current contract with SK are estimated at $127,528. Building 8100 alone accounts for $32,689 annually.

Onsite distillation in Building 8100 with a continuously flowing still was considered for option 2. Of the stills listed in Table 17, Finish Engineering's LS 15-2D still is the most economical option. The purchase price for a still with vacuum attachment and continuous flow package is $14,380. New parts washing sinks will need to be purchased to replace the 8 SK owned sinks in Building 8100. Table 18 has a list of various brands of parts washing sinks. An initial investment of $25,902 is required for option 2, and annual O&M costs are expected to be about $10,500. Compared with the cost of SK service in Building 8100 (option 1), option 2 results in NPV savings of $123,631 over the 10-year economic life used in the analysis. The SIR and DPP are 5.67 and 2.48 years, respectively.

Option 3 involves purchasing one large distillation unit and setting up a centralized distillation process for all of Fort Riley. The most economical still for this option is the SC100 from Progressive Recovery Inc. This option would also require the replacement of the 163 SK owned parts washing stations. Option 3 also requires significant labor for transporting the solvent to the centralized still. Initial costs to set up option 3 are estimated at about $228,506, with annual O&M costs of approximately $50,541. The SIR for option 3 with respect to option 1 is 1.77 with a DPP of 5.91 years.

Option 4 involves the same procedures as option 2, but with the addition of a centralized still for the solvent used on Fort Riley other than in Building 8100. This option would require the purchase of both the still selected in option 2 and the still selected in option 3. As in option 3, this option will require replacement of the 163 SK owned parts washing stations, and significant labor for transporting the solvent to the centralized still. The initial investment for option 4 is estimated at $247,854, with annual O&M costs of approximately $48,204. The SIR and DPP for option 4 with respect to option 1 are 1.68 and 6.26 years respectively.

Based on the cost analysis, it is recommended that Fort Riley implement option 2, which involves setting up a distillation unit in Building 8100 and maintaining the SK contract for the rest of Fort Riley. However, Fort Riley may not be willing to deal with the increased on-site personnel requirements and added liability in the case of spills or other mishaps. If the amount of money to be saved is not sufficient to offset these problems, Fort Riley should maintain the SK contract.

Lead-Acid Batteries/Battery Acid

Two different management options were considered for nonserviceable lead-acid batteries. Presently, Fort Riley is draining batteries for casing sale to a lead recycler and disposing of the acid as hazardous waste. The second option is to leave the batteries intact and recycle them with their acid through a battery recycler that will take the batteries whole (e.g., the Doe Run Lead Company, HWY KK, Boss, MO.)

Fort Riley generates approximately 26,000 lbs/yr of spent lead-acid battery electrolyte. Currently, Fort Riley must pay $2.36/lb to dispose of this acid. An estimated 300,000 lbs of battery casings are produced each year. These casings are auctioned semiannually by DRMO for an average sale price of $0.015/lb. The desired alternative is to discontinue the acid draining operation and sell the batteries with the electrolyte still inside (the Doe Run Lead Company quoted a price of $0.04/lb for whole lead-acid batteries.) This will result in an immediate payback. Fort Riley is presently paying about $56,860 annually to dispose of their used batteries. By discontinuing the acid draining operation and selling the batteries whole, Fort Riley could receive approximately $13,040 annually. Switching to the new alternative would save Fort Riley $69,900 annually and eliminate a hazardous waste stream. Before initiating this change, a conforming storage facility with ventilation, heating, and spill containment will need to be built. The effectiveness of this alternative will depend on training Fort Riley personnel in the proper handling of batteries to prevent cracked or leaking battery cases (which must be drained).

12 Summary and Recommendations

Summary

All Army installations that are generators or small quantity generators (according to RCRA definitions) are required to implement programs to reduce hazardous waste generation. Waste minimization is a method of preventing pollution with the primary focus on reducing waste generation. The benefits accrued by implementing a waste minimization program can be classified into the following four categories: economic, regulatory compliance, reduced liability, and positive public image/community relations.

Minimization of a particular waste can best be achieved by an appropriate combination of source reduction, recycling onsite/offsite, and treatment techniques. Source reduction is at the top of USEPA's hierarchy of waste management priorities. It is followed by recycling, waste separation and concentration, waste exchange, energy/material recovery, waste incineration/treatment, and, finally, ultimate disposal. A number of waste minimization techniques have been discussed in this report pertaining to wastes generated from motor pools/vehicle maintenance facilities; aviation maintenance facilities; industrial maintenance, small arms shops; paint shops; printing, photography, arts/crafts shops; hospitals, clinics, and laboratories; and other miscellaneous sources on typical FORSCOM Army installations.

Fort Riley is a troop combat training installation that primarily supports the mission assignment of the U.S. Army 1st Infantry Division (Mechanized). It is regulated by the USEPA as a generator of hazardous waste and owner and operator of a temporary hazardous waste treatment, storage, or disposal facility (i.e., DRMO). Fort Riley must report annually to the USEPA the quantity and types of hazardous waste managed for treatment or disposal. Hazardous waste management is additionally regulated by statutes promulgated by the State of Kansas.

A good hazardous waste management program has been established. A hazardous materials/hazardous wastes tracking program is currently being implemented at Fort Riley. Fort Riley is also seeking to update their Hazardous Waste Management Plan to comply with current regulations.

Used oil is the largest waste stream and is generated at the rate of approximately 130,000 gal/yr. Used oil is currently collected by an off-site contractor and blended with fuel to be burned in the contractor's boilers.

Spent lead-acid battery electrolyte (sulfuric acid) is generated at the rate of about 27,000 lb/yr and disposed through DRMO as a hazardous waste. The drained lead-acid battery casings (approximately 300,000 lb/yr) are strapped to wooden pallets and turned in to DRMO for recycling.

A closed-loop (Safety Kleen [SK]) contract has been established for recycling parts cleaning solvent used (36,815 gal/yr) by all the vehicle maintenance facilities. This contract also includes one paint gun cleaning unit that uses 49 gal/yr of solvent and 5 carburetor cleaning units that use a total of 210 gal/yr of carburetor cleaning solvent. Fort Riley also generates small quantities of several other solvents used for parts cleaning and wipe cleaning and are disposed through DRMO as hazardous wastes. These solvents amounted to approximately 575 gallons in 1991.

Some of the other large waste streams generated are other hazardous batteries, paint wastes, spent antifreeze solution, corrosive acids and bases, toxic hazardous wastes, and miscellaneous wastes.

An estimated total of 365 tons of hazardous wastes and 410 tons of controlled wastes were generated at Fort Riley in 1991. This estimate does not include PCB transformers. The hazardous waste estimate does include approximately 298 tons of hazardous materials that are recycled by off-site contractors. These materials technically should not be included as hazardous wastes since they are recycled. The remaining 67 tons of hazardous wastes were disposed of through DRMO.

The wastes selected for technical and economic analysis were used oils, spent antifreeze solution, spent cleaning solvent, and lead-acid battery electrolyte. The options examined include current practices (offsite disposal, burning, etc.), onsite recycling (distillation, filtration, etc.), contract recycling, segregation/processing, and process equipment modification. Most of the other wastes (e.g., pesticide wastes) can be minimized by implementing simple source reduction techniques (better operating practices).

Recommendations

A training program was established by the DES office to train personnel from each of the individual units in HM/HW handling and management. The training program should be examined to ensure compliance with 40 CFR 264.16. The training program should also include training on hazardous waste minimization.

DES personnel must conduct monthly inspections, minimization audits, and periodic training classes on recognizing/handling/storing hazardous materials and wastes. DES personnel should also continue their efforts in the development of inventories of quantities of hazardous materials used and wastes generated. These inventories should be updated periodically to reflect changes in activities or disbanding of activities.

Fort Riley should continue the implementation of their computer-based HM and HW tracking system. Tracking HM from the supply warehouse to generators and HW from the generators to final storage before disposal will provide a mass balance and aid in identifying future minimization opportunities.

All generators must develop an inventory system and maintain proper records of materials procured and wastes generated from each of the activities. These records must be inspected regularly by the supervisors and DES office personnel.

The hazardous waste management plan should be updated.

Implementation of the HAZMIN plan (Appendix A) should begin immediately; the plan should be updated by DES personnel annually.

Plan Implementation

Careful planning and a systematic approach are required to implement a successful waste minimization program. Three key elements (policy, commitment, and responsibility) are necessary for a strong program foundation.

The Commander must prepare a formal, written policy on waste minimization and pollution control, including its philosophy, objectives, and proper practices. Such a policy must be publicized in the installation newsletters and distributed to all military and civilian employees.

The installation command hierarchy and the commanders of tenant activities must adopt and support the policy statement. They should also willingly commit resources necessary to launch and support the waste minimization program.

A leader (such as the Chief, DES) should be appointed to oversee, direct, and assume all responsibility for the program. Supervisors and other employees of waste generating activities must be committed to the program for it to be effective. To encourage such a commitment, the Commanders and supervisors must implement motivational techniques. They must set goals for achieving waste/emissions reduction and provide incentives and awards for implementation of waste minimization ideas.

All waste generators must immediately implement HAZMIN options that require little or no capital investment (e.g., procedural or administrative changes) as discussed in Chapters 4 through 10. These options are generally characterized as "better operating practices," a subcategory of source reduction that does not require detailed technical and economic evaluation. Better operating practices are methods that achieve source reduction by (1) segregation (e.g., eliminate mixing of hazardous and nonhazardous wastes to improve their recyclability); (2) improved material handling and inventory practices (e.g., avoid accumulation of expired shelf-life materials, avoid spills, etc.); (3) preventive maintenance (e.g., prevent leaks and spills); (4) production scheduling (e.g., minimize quantities of unused raw materials and batch-generated wastes); and (5) minor operational changes.[150] Implementation of better operating practices usually requires only minimal employee training and changes to standing operating procedures (SOPs).

The recommended options, discussed in Chapter 11, for minimization of used oil, antifreeze solution, cleaning solvent waste, and batteries/battery acid should be funded (if necessary) and implemented.

The used oil disposal contract should be continued. However, a contractor should be sought who will re-refine the used oil (such as Safety Kleen) rather than burn it.

Spent antifreeze can be recycled as discussed in Chapter 4. An investment of $4709 is required to purchase a Glyclean recycling machine and chemical additives that it uses. With an annual savings of $41,545 compared to disposing the spent antifreeze as a controlled waste through DRMO, a payback period of 1.13 years is expected.

An onsite distillation program should be set up for the Consolidated Maintenance Facility. An initial investment of $25,902 will result in savings of approximately $12,360/yr and pay for itself in about 2.5 years. The current SK contract should be maintained for the rest of the installation.

---

150 National Association of Manufacturers, *Waste Minimization: Manufacturers' Strategies for Success* (ENSR Consulting and Engineering, 1989).

Wet recycling of lead-acid batteries is recommended in place of the current practice of draining spent electrolyte and disposing of it as hazardous through DRMO. A savings of $56,860/yr in acid disposal costs and an additional revenue of $13,040 can be expected when whole batteries are sold to a battery recycler. Labor costs will also be reduced by discontinuing the acid draining operation.

Generation of all other wastes can be reduced by more than 30 percent by managerial changes, training, and implementation of better operating practices and other appropriate minimization techniques as discussed in Chapters 4 through 10.

The Fort Riley Hazardous Waste Management Board, chaired by the Installation Commander, should adopt the HAZMIN plan and establish policies and procedures required for its implementation as soon as possible.

After implementing HAZMIN techniques at the generating activities, progress must be monitored and results recorded. The quantities of wastes generated before and after implementation of the techniques must be monitored and the achievements in waste minimization (e.g., percent minimized) documented.

It is vital to our environment that actions be taken to reduce hazardous waste generation. This report includes suggested methods for source reduction and recycling. Long-term hazardous waste minimization may require efforts beyond what is covered in this report. Many processes can be changed to reduce or eliminate individual HW streams, but these efforts may not always be cost-effective in the short term. The Army must be willing to work toward reaching the long term goals of reducing worker exposure to hazardous materials, reducing future liability costs, and improving the environment both locally and globally. By focusing on these long term goals, the Army can become a true leader in protecting our environment.

Metric Conversion Table

1 Btu = 2.93×10^{-4} kW-hr
1 gal = 3.785 L
1 in = 2.54 cm
1 mi = 1609 m
1 lb = 0.454 kg
1 psi = 6.895 kPa
1 ton = 0.907 metric tons
°C = 5 (°F - 32)/9

References

Cited

40 CFR 260, *Hazardous Waste Management System: General (1985).*

40 CFR 261, *Identification and Listing of Hazardous Waste* (1985).

40 CFR 262, *Standards Applicable to Generators of Hazardous Waste* (1985).

40 CFR 280-281, *Underground Storage Tanks: Technical Requirements and State Program Approval; Final Rule*, pp 37081 - 37247.

Acurex Corporation, *Navy Paint Booth Conversion Feasibility Study*, CR 89.004 (Prepared for the Naval Civil Engineering Laboratory [NCEL], Port Hueneme, CA, 1989).

Alternative Technology for Recycling and Treatment of Hazardous Wastes, Third Biennial Report (California Department of Health Services, Alternative Technology and Policy Development Section, 1986).

Anderson, C.W., *Cost-Effectiveness Analysis of Lubricant Reclamation by the Navy*, Technical Note 1481 (NCEL, Port Hueneme, CA, 1977).

Army Regulation (AR) 40-5, *Preventive Medicine* (HQDA, 30 August 1986).

ASTM Standard D 2847-85, "Standard Practice for Testing Engine Coolants in Car and Light Truck Service," *Annual Book of American Society of Testing and Materials Standards*, Vol 15.05 (American Society of Testing and Materials [ASTM], Philadelphia, PA, 1988).

ASTM Standard D 3640-80, "Standard Guidelines for Emission Control in Solvent Metal-Cleaning Systems," *Annual Book of American Society of Testing and Materials Standards*, Vol 15.05 (ASTM, 1988).

Brinkman, D.W., W.F. Marshall, and M.L. Whisman, *Waste Minimization through Enhanced Waste Oil Management*, NIPER B06803-1 (National Institute for Petroleum and Energy Research, 1987).

Brinkman, D.W., M.L. Whisman, and C.J. Thompson, *Management of Used Lubricating Oil at Department of Defense Installations: A Guide*, NIPER B06711-1 (National Institute for Petroleum and Energy Research, 1986).

Chance, R.L., M.S. Walker, and L.C. Rowe, "Evaluation of Engine Coolants by Electrochemical Methods," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, ed., ASTM STP 887 (ASTM, 1986), pp 99-102.

Cheremisinoff, P.N., "High Hazard Pollutants: Asbestos, PCBs, Dioxins, Biomedical Wastes," *Pollution Engineering*, Vol 21 (1989), pp 58-65.

Chicoine, L.C., G.L. Gerdes, and B.A. Donahue, *Reuse of Waste Oil at Army Installations*, Technical Report N-135/ADA123097 (U.S. Army Construction Engineering Research Laboratory [USACERL], September 1982).

Chylla, K. and Zipfel, G., *Economic Analysis for Minimizing Hazardous Wastes, Version 2.1: User's Manual*, ADP Report N-90/07/ADA219670 (USACERL, March 1990)

Ciccone, V.J. and Associates, Inc., *Program Status Report: Department of the Army Hazardous Waste Minimization* (U.S. Army Environmental Office, August 1988).

Comarco, Inc., *U.S. Navy Lithium Battery Disposal*, Report No. CESD-88-179 (Prepared for the Naval Weapons Support Center, High Energy Battery Systems Branch, Crane, IN, January 1989)

Conley, J.H. and R.G. Jamison, *Reclaiming Used Antifreeze*, Report 2168/ADA027100 (U.S. Army Mobility Equipment Research and Development Command [USAMERDC], Fort Belvoir, VA, 1976).

Darvin, C.H. and R.C. Wilmoth, *Technical, Environmental, and Economic Evaluation of Plastic Media Blasting for Paint Stripping*, USEPA/600/D-87/028 (U.S. Environmental Protection Agency [USEPA], Water Engineering Research Laboratory, 1987).

Defense Hazardous Materials Handling Course (DHMHC), U.S. Army Logistics Management Center (ALMC), Fort Lee, Virginia.

Defense Utilization and Disposal Manual, DOD 41620.21-M (Defense Logistics Agency, Office of the Assistant Secretary of Defense, Alexandria, VA, September 1982), pp VI-42 and XVII-A-5 to XVII-A-10.

Department of Defense Memorandum for Deputy of Environment, Safety and Occupational Health, OASA (I&L); Deputy Director for Environment, OASN (S&L); Deputy for Environment and Safety and Occupational Health (SAP/MIQ); Director, Defense Logistics Agency (DLA-S); 28 January 1986, Subject: "Regulation of Used Oil for Burning."

Dharmavaram, S., et al., "A Profile and Management of the U.S. Army's Underground Storage Tanks," *Environmental Management*, Vol 13 (1989), pp 333-338.

Donahue, B.A. and M.B. Carmer, *Solvent "Cradle-To-Grave" Management Guidelines for Use at Army Installations*, Technical Report N-168/ADA137063 (USACERL, December 1983).

Donahue, B.A., T.J. Hoctor, and K. Piskin, *Managing Underground Storage Tank Data Using dBase III Plus*, Technical Report N-87/21/ADA182452 (USACERL, June 1987).

Donahue, B.A., et al., *Used Solvent Testing and Reclamation, Volume I: Cold-Cleaning Solvents*, Technical Report N-89/03/ADA204731, Vol I (USACERL, December 1988).

Donahue, B.A., et al., *Used Solvent Testing and Reclamation, Volume II: Vapor Degreasing and Precision Cleaning Solvents*, Technical Report N-89/03/ ADA204731, Vol II (USACERL, December 1988).

Drabkin, M., C. Fromm, and H.M. Freeman, "Development of Options for Minimizing Hazardous Waste Generation," *Environmental Progress*, Vol 7 (1988), pp 167-173.

Durney, L.J., "How to Improve Your Paint Stripping," *Product Finishing* (December 1982), pp 52-53.

Ecology and Environment, Inc., *Waste Audit Study - General Medical and Surgical Hospitals* (California Department of Health Services, Sacramento, CA, 1988).

Efficient Boiler Operations Sourcebook, F.W. Payne, ed. (The Fairmont Press, Inc. Atlanta, GA, 1986), pp 79-106.

Electroplating Engineering Handbook, Fourth Edition, L.J. Durney, ed. (Van Nostrand Reinhold Company, 1984).

EPA (Environmental Protection Agency) Manual for Waste Minimization Opportunity Assessments, EPA/600/2-88-025 (USEPA, Hazardous Waste Engineering Research Laboratory, 1988).

Evaluation of Lithium Sulfur Dioxide Batteries, US Army Communications - Electronics Command and US Electronics Research and Development Command, Fort Monmouth, New Jersey, USAEHA-37-26-0427-85 (USAEHA, Aberdeen Proving Ground, MD, 1985)

Federal Register, Vol 51, No. 190 (October 1986), pp 35190-35194.

Fiaud, C., et al., "Testing of Engine Coolant Inhibitors by an Electrochemical Method in the Laboratory and in Vehicles," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, ed., ASTM STP 887 (ASTM, 1986), pp 162-175.

Fu, T.T. and R.S. Chapler, *Utilization of Navy-Generated Waste Oils as Boiler Fuel - Economic Analysis and Laboratory Tests*, Technical Note N-1570 (U.S. Navy Construction Battalion Center, 1980).

Gardner, J., *Dry Paint Stripping Utilizing Plastic Media: A New Solution to an Old Problem*, Technical Bulletin (Clemco Industries, 1987).

Garrard, W.N., *Introduction to Lithium Batteries*, MRL-GD-0018; DODA-AR-005-652 (Materials Research Laboratory, Ascot Vale, Australia, 1988).

Gibbs, L.M., "Recovery of Waste Organic Solvents in a Health Care Institution," *American Clinical Products Review* (November/December 1983).

GLYCLEAN - Antifreeze Recycling System, brochure (FPP Chemical Co., Inc., Buffalo, NY, 1992).

Guide to Infectious Waste Management, EPA/530-SW-86-014 (USEPA, Washington, DC, 1986).

Hart Associates, Fred C., *Aerospace Waste Minimization Report* (California Department of Health Services and Northrop Corporation, 1987).

Hazardous Waste Minimization (HAZMIN) Policy (Department of the Army, 1989).

Hazardous Waste Reduction Assessment Handbook - Automotive Repair Shops (California Department of Health Services, Toxic Substances Control Division, 1988), 24 pp.

Hazardous Waste Reduction Checklist - Automotive Repair Shops (California Department of Health Services, Toxic Substances Control Division, 1988).

Hemstreet, R.H., "How to Conduct Your Waste Minimization Audit," in *Waste Minimization Manual* (Government Institutes, Inc., Rockville, MD, 1987), pp 61-75.

Hunt, G.E., and R.N. Schecter, "Minimization of Hazardous-Waste Generation," in *Standard Handbook of Hazardous Waste Treatment and Disposal*, H. M. Freeman, ed. (McGraw Hill, New York, NY, 1988), pp 5.3-5.27.

ICF Associates, Inc., *Guide to Solvent Waste Reduction Alternatives: Final Report* (Prepared for California Department of Health Services, October 1986).

Infectious Hazardous Waste Handling and Disposal, Technical Guide Number 147 (USAEHA, MD, 1986).

Isooka, Y., Y. Imamura, and Y. Sakamoto, "Recovery and Reuse of Organic Solvent Solutions," *Metal Finishing* (June 1984), pp 113-118.

Jacobs Engineering Group, Inc., *Waste Audit Study - Commercial Printing Industry* (California Department of Health Services, Sacramento, CA, May 1988).

Joint Logistics Commanders, "Hazardous Waste Minimization Program," Memorandum to the Deputy Secretary of Defense (12 December 1985).

Kohl, J., P. Moses, and B. Triplett, *Managing and Recycling Solvents: North Carolina Practices, Facilities, and Regulations* (North Carolina State University, Raleigh, NC, 1984).

Kraybill, D., T. Mullen, and B.A. Donahue, *Hazardous Waste Surveys of Two Army Installations and an Army Hospital*, Technical Report N-90/ADA088260 (USACERL, August 1980).

Layman, P.L., "Paints and Coatings: the Global Challenge," *Chemical and Engineering News* (September 30, 1985), pp 27-68.

Layton, D.W., et al., *Demilitarization of Conventional Ordnance: Priorities of Data-Base Assessments of Environmental Contaminants*, UCRL-15902 (USAMRDC, Fort Detrick, MD, 1986).

Makwinski, J. and P.N. Cheremisinoff, "Special Report: Underground Storage Tanks," *Pollution Engineering*, Vol 20 (1988), pp 60-69.

Managing Empty Containers, Fact Sheet (Minnesota Technical Assistance Program, University of Minnesota, Minneapolis, MN, 1988).

Mark, F.E. and W. Jetter, "Propylene Glycol, A New Base Fluid for Automotive Coolants," in *Engine Coolant Testing: Second Symposium*, R.E. Beal, ed., ASTM STP 887 (American Society of Testing and Materials [ASTM], 1986), pp 61-77.

Medical Waste Sanctions Act of 1988, Report 100-1102 (House of Representatives, 100th Congress, October 1988).

Military Specifications Mil-L-46152, *Lubricating Oil, Internal Combustion Engine, Administrative Service, Metric* (DOD, 1 August 1988).

Military Specification MIL-A-46153, *Antifreeze, Ethylene Glycol, Inhibited, Heavy Duty, Single Package* (DOD, 31 July 1979).

Military Specification MIL-A-53009, *Additive, Antifreeze Extender, Liquid Cooling System (Department of Defense [DOD]*, 6 August 1982).

Minimization of Hazardous Waste. Executive Summary and Fact Sheet, EPA/530/SW-86/033A (USEPA, Office of Solid Waste, 1986).

National Association of Manufacturers, *Waste Minimization: Manufacturers' Strategies for Success* (ENSR Consulting and Engineering, 1989).

National Research Council, *Prudent Practices for Disposal of Chemicals from Laboratories* (National Academy Press, Washington, DC, 1983).

Nester, F.W. and L.L. Smith, *Propellant Reuse Technology Assessment*, AMXTH-TE-CR-86076 (USATHAMA, Aberdeen Proving Ground, MD, 1986).

Office of the Assistant Chief of Engineers, "Hazardous Waste Disposal Funding," DAEN-ZCP-B Memorandum (Department of the Army, 28 October 1988).

Prolonging Machine Coolant Life, Fact Sheet (Minnesota Technical Assistance Program, Minneapolis, MN, 1988).

Protocol Health Care Facility Waste Management Surveys (USAEHA, Aberdeen Proving Ground, MD, 1987).

Public Law 94-480, *Resource Conservation and Recovery Act* (1976).

Public Law 98-616, *Hazardous and Solid Waste Amendments* (1984).

Public Law 99-499, *Title III, Superfund Amendments and Reauthorization Act* (1986).

Reinbold, K., M.A. Curvey, and P.T. Conroy, *PCB Transformer User Manual: PC Version*, Automatic Data Processing (ADP) Report EP-93/03/Unpublished (USACERL, February 1993).

Reinbold, K., M.A. Curvey, and P.T. Conroy, *PCB Transformer System User Manual: ETIS Version 2.0*, ADP Report EP-93/02/ADA269192 (USACERL, February 1993).

Resch, M.E., "Hazardous Waste Minimization Audits Using a Two-tiered Approach," *Environmental Progress*, Vol 7 (1988), pp 162-166.

Salvesan, R.H., Associates, *Used Oil and Solvent Recycling Guide*, Final Report (Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1985).

SCS Engineers Inc., *Waste Audit Study - Automotive Paint Shops* (California Department of Health Services, Sacramento, CA, January 1987).

Standard Handbook of Hazardous Waste Treatment and Disposal, Freeman, H.M., ed. (McGraw Hill, New York, NY, 1989).

Technical Manual (TM) 9-1300-214, *Military Explosives* (HQDA, 20 September 1984).

Toy, W.M., *Waste Audit Study - Automotive Repairs* (Prepared for the California Department of Health Services, Sacramento, CA, 1987).

Ventura County Environmental Health, *Hazardous Waste Reduction Guidelines for Environmental Health Programs* (California Department of Health Services, Sacramento, CA, 1987).

Winslow, H., *Hazardous Waste SQG Workbook* (Intereg Group, Inc., Chicago, IL, 1986).

Woodhouse, C., *Waste Ink Reclamation Project* (California Department of Health Services, Toxic Substances Control Division, August 1984).

Uncited

Army Regulation (AR) 40-5, *Preventive Medicine* (Headquarters, Department of the Army [HQDA], 30 August 1986).

AR 200-1, *Environmental Protection and Enhancement* (HQDA, 15 June 1982).

Beller, J.M., et al., *Biodegradable Solvent Substitution - A Quick Look Report* (U.S. Air Force Logistics Commands, Tyndall Air Force Base, FL, 1988).

Campbell, M.E. and W.M. Glenn, *Profit from Pollution Prevention - A Guide to Industrial Waste Reduction and Recycling* (The Pollution Probe Foundation, Toronto, Canada, 1982).

Conley, J.H. and R.G. Jamison, "Additive Package for Used Antifreeze," in *Engine Coolant Testing: Second Symposium,* R.E. Beal, ed., ASTM STP 887 (ASTM, Philadelphia, PA, 1986).

Dharmavaram, S., D.A. Knowlton, and B.A. Donahue, *Hazardous Waste Minimization Assessment: Fort Carson, CO*, Technical Report N-91/02/ADA232241 (USACERL, January 1991).

Dharmavaram, S., et al., "Hazardous Waste Minimization at Army Installations," Paper No. 88-11.4 (Presented at the 81st Annual Meeting of Air and Waste Management Association, Dallas, TX, 1988).

Drycleaning and Laundry Plants, Hazardous Waste Fact Sheet (Small Quantity Generators Activity Group, Minnesota Technical Assistance Program, University of Minnesota, Minneapolis, MN, 1988).

Economic Analysis of Solvent Management Options, Technical Note 86-1, (Department of the Army, May 1986).

Economic Implications of Waste Reduction, Recycling, Treatment and Disposal of Hazardous Wastes, The Fourth Biennial Report (California Department of Health Services, Sacramento, CA, July 1988).

The EPA Manual for Waste Minimization Opportunity Assessment, EPA/600/2-88-025 (USEPA, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, 1988).

Federal Register, Vol 50, No. 23, pp 49164-49249.

Fortuna, R.C. and D.J. Lennett, *Hazardous Waste Regulation - The New Era* (McGraw Hill, New York, NY, 1987).

Hazardous Waste Minimization: Corporate Strategies and Federal/State Initiatives (Government Institutes, Inc., Rockville, MD, 1988).

Higgins, T.E., *Hazardous Waste Minimization Handbook* (Lewis Publishers, Inc., Chelsea, MI, 1989).

Huisingh, D., *Profits of Pollution Prevention: A Compendium of North Carolina Case Studies* (North Carolina Board of Science and Technology, Raleigh, NC, 1985).

Jacobs Engineering Group, *Hazardous Waste Minimization Potential Workbook* (Prepared for the California Department of Health Services, Sacramento, CA), 65 pp, 1987.

Jones, E.B., W. Banning, and R.C. Herndon, "Waste Exchanges and Waste Minimization and Reclamation Efforts," in *Waste Minimization Manual* (Government Institutes, Inc., Rockville, MD, 1987), pp 78-85.

Management/Equipment Evaluation Program, Report H82-1B (1st Space Support Group, U.S. Air Force, Peterson Air Force Base, CO, 1983).

Mount, J.B., et al., *Economic Analysis of Hazardous Waste Minimization Alternatives*, TR EN-92/05/ ADA256989 (USACERL, August 1989).

Reay, W.H., "Solvent Recovery in the Paint Industry," *Paint & Resins* (March/April 1982), pp 41-44.

Technical Note 86-2, *Solvent Minimization and Substitution Guidelines* (Department of the Army, Office of the Chief of Engineers, Washington, DC, 1986), 18 pp.

Union Carbide Corporation, *Ecological Aspects of UCAR Deicing Fluids and Ethylene Glycol* (Hazardous Materials Technical Center, Rockville, MD, 1984).

Appendix A: Fort Riley - HAZMIN Plan

1. BACKGROUND

The Hazardous and Solid Wastes Amendments (HSWA)[1] to the Resource Conservation and Recovery Act (RCRA),[2] passed in 1984, require the generators of hazardous wastes to certify that they have a waste minimization program. Every waste shipment manifest contains the following declaration, in compliance with Section 3002 (b) of HSWA:

> The generator of the hazardous waste has a program in place to reduce the volume and toxicity of such waste to the degree determined by the generator to be economically practicable;...

Therefore, all facilities that meet the RCRA definitions of Generator (more than 1000 kg or 2205 lb/month) and Small Quantity Generator (100 to 1000 kg or 220 to 2205 lb/month) of HW are required to implement waste minimization programs.

HSWA [Section 3002(a)] also requires the generators of hazardous wastes to submit a biennial report, including documentation on efforts to reduce the volume and toxicity of wastes generated. Facilities that treat, store, or dispose of hazardous wastes are required by HSWA, Section 3005(h) to submit annual reports accompanied with similar declarations on waste minimization.

In the broadest sense, HAZMIN may be defined as the process of reducing the net outflow of hazardous waste effluents from a given source (or generating process). Minimization includes reductions in the generation of hazardous wastes as well as recycling activities. Recycling can result in either a reduction in the total volume or quantity of hazardous wastes, or a reduction in the toxicity of hazardous wastes produced, or both, as long as it is consistent with

---

1 Public Law 98-616, *Hazardous and Solid Waste Amendments*, 1984.

2 Public Law 94-480, *Resource Conservation and Recovery Act*, 1976.

the national goal of minimizing present and future threats to the environment.[3] HAZMIN, therefore, can be achieved by three different methods:

Source Reduction - reduction or elimination of waste generation at the source, usually within a process;

Recycling Onsite/Offsite - the use or reuse of a waste as an effective substitute for a commercial product, or as an ingredient or feedstock in a process; or the reclamation of useful constituent fractions from within a waste or removal of contaminants to allow the material to be reused; and/or

Treatment - elimination of hazardous characteristics of a waste in order to make it nonhazardous to human health and the environment.

For any particular waste, the minimization options must be evaluated in the hierarchy of source reduction first, followed by recycling (including, recovery and reuse), and, finally, treatment. Some small amount of residue (e.g., ash) which will require "ultimate" disposal (e.g., landfill burial) may always remain. Although attempts have been made to clearly define the three HAZMIN categories, there may be overlap for certain specific techniques. Maximum waste reduction is usually achieved by using the best combination of suitable techniques from all three categories.

Recognizing the liabilities of improper disposal and the advantages of waste minimization, the Joint Logistics Commanders set a DOD-wide goal of 50 percent reduction in hazardous waste generation by 1992, based on the baseline generation in 1985. The Department of the Army has adopted this DOD goal and established a policy applicable to all Active Army, Reserve, and National Guard installations.[4]

2. PURPOSE

The purpose of the Fort Riley Installation Hazardous Waste Minimization (HAZMIN) plan is to provide a specific plan of action to reduce the quantities

---

3 *Minimization of Hazardous Waste. Executive Summary and Fact Sheet*, EPA/530/SW-86/033A (EPA, Office of Solid Waste, Washington, D.C., 1986).

4 Office of the Assistant Chief of Engineers, "Hazardous Waste Minimization (HAZMIN) Policy," Department of the Army, 1989, 15 pages.

and toxicities of hazardous wastes (HW) generated within the installation boundaries.

3. SCOPE

The scope of the plan extends to all the HW regulated under the Resource Conservation and Recovery Act (RCRA), the Hazardous and Solid Wastes Amendments (HSWA), and the State of Kansas Hazardous Waste Regulations.

4. GOALS

4.1 Department of Army (DA) HAZMIN Goals

Process, Operation, or Condition	Percent HW Reduction Desired by 1992
Cleaning/degreasing	40
Transportation vehicle maintenance	0
Fueling operations	30
Battery shop operations	50
Painting	50
Sand blasting	60
Metalworking	15
Graphic Arts	40
Electrical maintenance	60
Waste treatment sludge	60

4.2 Fort Riley HAZMIN Goals

Same as DA HAZMIN goals.

4.3 HAZMIN Reduction Estimation

Percent HW reduction for any calendar year (CY) =

$$\frac{\text{(Baseline Year HW Generation - CY HW Generation) * 100}}{\text{Baseline Year HW Generation}}$$

5. PROGRAM MANAGEMENT

5.1 Fort Riley will manage the HAZMIN program according to AR 200-1 and AR 420-47. The installation's Hazardous Waste Management Board (HWMB) shall review and adopt this plan, and establish other policies and procedures for implementation. The HWMB is to be chaired by the Assistant Division Commander (Support) and consists of the following members:

Assistant Division Commander (Support) (ADC/S)
Garrison Commander (GC)
Director of Environment and Safety (DES)
Director of Logistics (DOL)
Director of Personnel and Community Activities (DPCA)
Director of Plans, Training, and Mobilization (DPTM)
Assistant Chief of Staff (ACofS, G1/AG)
Assistant Chief of Staff (ACofS, G2)
Assistant Chief of Staff (ACofS, G3)
Assistant Chief of Staff (ACofS, G4)
Assistant Chief of Staff (ACofS, G5)
Deputy Chief of Staff (DCS)
Inspector General (IG)
Chief, Defense Reutilization and Marketing Office (DRMO)
Manager, Safety Office
Public Affairs Officer (PAO)
Staff Judge Advocate (SJA)
Chief, Resource Management Branch
Director of Health Services (DHS)
Director of Dental Services (DDS)
Commander, 1st Brigade

Commander, 2nd Brigade
Commander, 4th Brigade (Aviation)
Commander, Division Artillery
Commander, Division Support Command
Commander, 937th Engineer Group
Commander, 34th Engineer Battalion
Commander, 121st Signal Battalion
Commander, 101st Military Intelligence Battalion
Commander, 2nd Battalion, 3rd Air Defense Artillery
Commander, 1st Engineer Battalion
Commander, Headquarters Command

5.2 The activities at Fort Riley that are generators of hazardous waste, used oil, and miscellaneous toxic wastes; and references to the appropriate chapter (in the assessment technical report) are

	Chapter Number
Motor Pools/Vehicle Maintenance Facilities	3, 4
Aviation Maintenance Facilities	3, 4
Industrial Maintenance, Small Arms Shops, etc.	3, 5
Paint Shops	3, 6
Photography, and Printing Operations	3, 7
Hospitals, Clinics, and Laboratories	3, 8
Other Generators	3, 9

6. TRAINING

6.1 Personnel Training

A training program will be developed by the Director, DES for personnel involved in handling hazardous materials and managing hazardous wastes to ensure compliance with 40 CFR 264.16.

6.2 Training Content, Schedules, and Techniques

Personnel from HW generating activities must be given supervised on-the-job training as well as formal courses. The formal courses must be designed similar to the program offered by the U.S. Army Environmental Hygiene

Agency, or the U.S. Army Logistics Management Center. Refresher courses should be taught by personnel from the DES.

The objective of a formal (or refresher) course must be to provide each student with the abilities to do the following:

1. Recognize, identify, and classify hazardous materials.
2. Take actions necessary to prevent hazardous chemical incidents, protect personnel health, and prevent damage to the environment.
3. Properly package, label, store, handle, and transport hazardous materials and hazardous waste.
4. Take immediate action in response to hazardous materials spills or other emergencies.
5. Implement appropriate HAZMIN techniques.
6. Properly manage the resources under his/her control to prevent violation of applicable laws, regulations, and policies.[5]

6.3 Implementation of Training Program

The Hazardous Waste Manager will present the training program designed by the Director, DES. The Chief of the Training Division (DPTM) will ensure that all new and/or reassigned personnel will not work in positions dealing with hazardous materials/wastes unless they have completed the appropriate program within 75 days (as per Fort Riley SOP) of the date of employment or reassignment. All supervisors will, annually, review the training status of their personnel.

6.4 Records

6.4.1 The Personnel Directorate (Fort Riley and tenant activities) will maintain records pertaining to job experience and the training completion requirements. The records must include description of the type/nature of initial and continuing training each person receives.

---

5 *Defense Hazardous Materials Handling Course (DHMHC)*, U.S. Army Logistics Management Center (ALMC), Fort Lee, Virginia.

6.4.2 Fort Riley will maintain records of all current personnel until deactivation of a particular unit/organization or the entire base. Training records of past employees must be kept for at least 3 years after the date of last employment.

7. HAZMIN ACTIONS

7.1 General Actions

7.1.1 Command Initiatives: For the HAZMIN program to be successful, the Commander and the chain of command for all the troops and tenants must make a commitment to all the goals (section 4) and establish specific goals at the generator (or activity) level.

The Installation Commander will develop an environmental policy statement emphasizing pollution minimization and assign direct responsibility to all personnel as protectors of the environment in their day-to-day work. All personnel will be notified (through the installation's newspaper and inter-office memorandums) regarding the command commitment and goals.

Personnel incentives (such as awards, commendation, etc.) must be provided to encourage new HAZMIN ideas and to reward implementation of successful HAZMIN projects.

7.1.2 The installation must solicit cooperation with the host communities (Junction City and Manhattan) for success of HAZMIN projects.

7.1.3 Participation in implementation, programming, and budgeting HAZMIN programs is required among appropriate personnel from the following: Directorate of Logistics (DOL) - responsible for supply/procurement, transportation; Directorate of Environment and Safety (DES) - responsible for interim and long term storage, compliance with Federal/State environmental laws, and pollution control guidance; and Defense Reutilization and Marketing Office (DRMO) - responsible for proper disposal.

7.1.4 A hazardous material (HM) and hazardous waste (HW) tracking (manifest) program will be implemented at Fort Riley (including all the tenants). Tracking HM from the supply warehouse to generators and HW from the generators to final storage before disposal, will provide a mass balance and improve minimization opportunities.

7.1.5 HAZMIN programs will be incorporated into the agenda of the Environmental (and Hazardous Waste) Management Board Meetings. Proper coverage must be provided in the installation newspaper to ensure wide acceptance among personnel.

7.1.6 Director, DES, and the Installation Safety and Occupational Health Manager will combine resources to develop a training program for personnel in hazardous materials/waste handling and emergency response (according to Section 6) which is required by law.

7.1.7 Director, DES, will develop a waste analysis program to characterize and define all (air, water, liquid, and solid) waste streams from all the generators to ensure compliance with Federal and State laws.

7.1.8 Director, DRMO, and the Director, DES, will examine the use of waste exchange programs as a proper recycle methodology for some of the hazardous wastes.

7.1.9 The DES Hazardous Waste Program Manager will conduct monthly inspections, minimization audits, and periodic training classes in recognition/handling/storage of hazardous materials and wastes.

7.2 Generator Actions

7.2.1 All generators will appoint environmental (hazardous waste) coordinators who would be responsible for minimizing generation (of air emissions, water pollution and solid wastes), proper interim storage, and turn-in of hazardous wastes.

7.2.2 The environmental (or hazardous waste) manager should interface with the DES Hazardous Waste Program Manager in all matters pertaining to waste management and minimization. Individuals appointed to this duty will devote more time than is customary for a typical extra duty.

7.2.3 All environmental managers will maintain proper records (logbooks) of materials procured and wastes generated from each activity and report monthly to the DES.

7.2.4 All generators must, with the help of DES, completely characterize (in terms of composition, periodicity of generation, why and how generated, etc.) all the waste streams, and document and provide relevant data when requested by the DES.

7.2.5 All generators will include HAZMIN requirements ("Better Operating Practices" as outlined in Chapters 4 through 10) and specified by the DES in their standing operating procedures (SOPs).

7.3 Current HAZMIN Projects

7.3.1 Cleaning Solvent - Recycle Onsite/Offsite - Contract Recycling: A used solvent recycling contract has been established with Safety Kleen (SK) to collect and recycle the used cleaning solvent (petroleum naphtha) used in motor pools, vehicle/aviation maintenance facilities, and other parts cleaning activities. Source reduction (e.g., better operating practices, testing, etc.) must be implemented by all generators to reduce the quantities used.

Under the current SK contract, 37,074 gallons of solvent are used at Fort Riley in a year. The consolidated maintenance facility (Building 8100) is the largest solvent user at Fort Riley, accounting for 9,937 gal/yr. Based on economic analysis, onsite distillation (using a 15-gal batch still with continuous fill and automatic shut-down) is more economical than the current SK contract to recycle spent cleaning solvent in Building 8100. A distillation unit should be installed in Building 8100. The SK contract should be continued for the rest of Fort Riley. Use of other solvents that are currently disposed of through DRMO should be examined. Where possible, petroleum naphtha should be substituted for these solvents and included in the SK contract. The costs below are for implementation of onsite distillation in Building 8100. The cost of the SK contract for the rest of the installation is not included.

Estimated Cost: Investment - $25,902; Annual O&M - $10,560

Estimated Annual Savings: $22,129

Estimated Payback Period: 2.44 years

Estimated Waste Reduction (Better Operating Practices and Product Substitution): 40 percent

Estimated Solvent Hazardous Waste Reduction (current practice): 95-98 percent

Estimated H.W. Reduction (Better Operating Practices and Onsite Distillation): 100 percent

7.3.2 Used Oil - Offsite Recycling: Used oil is not classified as hazardous waste, but is included here as a controlled waste. Used oil is currently accumulated by all the generators in underground storage tanks. A contractor collects the oil and transports it to a blending and burning operation owned by the contractor. About 130,000 gal/yr of used oil is generated. Proper segregation of waste oil is required at all the generators.

Safety Kleen, Inc. can provide oil recycling service in which the oil is taken to a SK owned re-refinery. The re-refined oil is suitable for use as motor lubricating oil. With the possibility of used oil being classified as hazardous waste, and with many people questioning the validity of claiming blending and burning as recycling, it is recommended that Fort Riley use the SK oil service.

Estimated Cost: Investment - $0; Annual O&M - unknown

Estimated Annual Savings: unknown

Estimated Payback Period: unknown

Estimated Waste Reduction (Waste Oil Recycling): 99 percent

Estimated Hazardous Waste Reduction: Not Applicable

7.3.3 Spent Lead-Acid Batteries/Battery Acid - Source Reduction - No Draining/Sale: The current practice at Fort Riley is to drain lead-acid batteries and dispose of the spent acid as hazardous waste. About 26,000 lbs/yr of acid and about 300,000 lbs/yr of battery casings are generated. The empty battery casings are sold to a recycler by DRMO.

Elimination of the battery draining operation is recommended. Lead-acid batteries (sealed and unsealed) must be accumulated at the generators (e.g., motor pools) on pallets. These batteries, which still contain the spent acid, can be recycled through a recycler. If the batteries are being recycled, they are exempt from RCRA reporting requirements and, therefore, do not require reporting and manifesting paperwork necessary for other hazardous wastes.

Estimated price: Investment - $0; Annual O&M - ($13,040) (revenue)

Estimated Annual Savings: $69,900

Estimated Payback Period: Immediate

Estimated Waste Reduction (Source Reduction/Recycling): 100 percent

Estimated Hazardous Waste Reduction: 100 percent

7.3.4 Used Antifreeze Solution - Onsite Recycling: Fort Riley is presently disposing of approximately 3350 gal/yr of used antifreeze as a controlled waste through DRMO. A technology (Glyclean filtration system - unit price: $3,500) exists for recycling the 50 percent antifreeze solution. Use of the Glyclean system is recommended.

Estimated Cost: Investment - $4,709; Annual O&M - $2,731

Estimated Annual Savings: $41,545

Estimated Payback Period: 1.13 years

Estimated Waste Reduction (Recycling): 100 percent

Estimated Hazardous Waste Reduction: Not Applicable

7.3.5 Photograph Developing Solution- Silver Recovery: Fort Riley's photography laboratory and printing plant employ developing units. The photography labratory reuses chemicals in the black and white processor to achieve a 50 percent reduction in waste generation. All developing chemicals from the print plant and photography labratory are run through a silver recovery unit. The remaining chemicals and the discharge from the silver recovery units are biodegradable; alkaline solutions and are flushed down the drain to the sanitary sewer.

Estimated Waste Reduction: 50%

Estimated Hazardous Waste Reduction: 100%

7.3.6 Off-Spec/Contaminated Fuels - Source Reduction/Reuse: Contaminated or off-spec gasoline, JP-4 and diesel fuel were formerly disposed of through DRMO as hazardous wastes. Current practice for gasoline and JP-4 is to take them to the burn pit for use in fire training. This has eliminated disposal of this hazardous waste stream and reduced the need to purchase fuel for fire training operations. Contaminated diesel fuel is pumped into a Hemmit and run through the water separator and fuel filter. The fuel can then be used.

Estimated Waste Reduction: 100%

Estimated Hazardous Waste Reduction: 100%

7.4 Future HAZMIN Projects

7.4.1 Plastic Media Blasting: Plastic media blasting (PMB) may be an economical alternative to the sand blasting operation in Building 8100. Sand blasting provides good cleaning for part preparation, but the sand is difficult to recycle because it will shatter when striking the object being cleaned. This makes it very difficult to separate and reuse the sand. One of the major advantages of PMB is that it is much more resilient and can be recycled 10 to 20 times, resulting in lower replacement and disposal costs. Usually, existing sand blasting units can be modified to use plastic blasting media with only minor changes to the blast media and air flow rates. The blasting nozzle may also need to be replaced, but this can be done rather inexpensively. The information available on Fort Riley's use of sand blasting was insufficient to allow for an economic analysis of PMB. Fort Riley personnel should evaluate PMB to determine if it could be used in their current sand blasting unit, and if the plastic media could achieve the desired cleaning results in a cost-effective manner.

7.4.2 High-Volume Low-Pressure Painting: High-Volume Low-Pressure (HVLP) painting is a technology that reduces the amount of overspray in painting operations. It is presently used in Navy CARC applications. Because overspray is reduced, more of the paint ends up on the object being painted, which will increase the life of the paint booth filters to provide a secondary cost benefit. Due to the significant painting operations that took place during 1989 and 1990, it is difficult to determine "typical" paint use and paint waste generation rates for Fort Riley. Use of the HVLP painting system could substantially reduce the amount of paint used at Fort Riley. The HVLP painting system is available from CAN-AM Engineered Products, Inc. at an approximate cost of $17,500 for one HVLP painting machine with four spray guns that can be operated simultaneously. Fort Riley should examine their painting needs and waste generation to determine if the purchase and use of this system would be cost-effective.

7.4.3 Dry Cleaning Solvent: The dry cleaning plant at Fort Riley currently owns dry cleaning machines that use tetrachloroethylene (also called perchloroethylene or PERC) as dry cleaning solvent. PERC is moderately toxic and is an irritant to eyes and skin. The human tolerance level for PERC is 100 ppm in air. Any waste containing more than 0.7 mg/L of PERC is classified as hazardous by the USEPA. PERC is also on the list of Hazardous Air Pollutants regulated under the Clean Air Act Amendments of 1990. The advantage of using PERC is that it is explosion-proof.

According to the manufacturer, the current dry cleaning equipment at Fort Riley cannot be converted to operate with a less toxic solvent. One of the difficulties in using a less toxic dry cleaning solvent such as PD-680 is its low flash point. The dry cleaning machines would have to be replaced with units designed to be explosion proof. Due to the toxicity of PERC and the impending air pollution emission regulations for PERC dry cleaning plants, it is recommended that Fort Riley consider changing to a less toxic dry cleaning alternative when the current dry cleaning equipment is scheduled for replacement.

7.4.4 Other Wastes - Source Reduction: Implement better operating practices and other appropriate minimization techniques according to references in Section 5.2.

Estimated Waste Reduction: 30 percent

Estimated Hazardous Waste Reduction: 20 percent

8. REFERENCES

8.1 A summary of Fort Riley installation waste generation data is presented in Table A1. For more detailed information, refer to Tables 3 through 15 in Chapter 3.

8.2 This plan is in Appendix A of the *Hazardous Waste Minimization Assessment: Fort Riley, Kansas.*

9. IMPLEMENTATION

Estimated Implementation Date: May 1, 1994

10. RESPONSIBILITIES

10.1 The duties and responsibilities of persons directly responsible for implementation of this plan and success of the HAZMIN program are described in this section. The following personnel will form the Fort Riley HAZMIN committee that will oversee the implementation of this plan and keep it revised and updated in the future.

Job Title	HAZMIN Activity
Chief, Directorate of Environment and Safety (DES)	Overview of the entire program; chair the committee; and others as noted in section 10.3.
Chief, DES Pollution Prevention	Vicechair of the committee. Help the Director, DES and coordinate implementation with the hazardous waste program manager and other committee members.
Hazardous Waste Manager, DES Pollution Prevention	Establish a hazardous materials/ waste training program; establish waste inventory and inspection program; establish a HW/HM tracking program; coordinate with Safety Officer, Fire Director, DRMO and all the environmental coordinators.
DES, Installation Safety Division	Establish a chemical inventory program; flag and control purchase of hazardous materials; coordinate with the environmental engineer regarding maintaining and updating inventory.
Chief, Defense Reutilization and Marketing Office	Establish proper waste turn-in procedures; waste contract management; explore offsite reclamation and waste exchange options.

Chief, DES Maintenance Division	Inventory control of materials and wastes; vehicle/equipment maintenance, painting and laboratory wastes minimization; pesticides management; PCB transformer inventory management.
Chief, DES Fire Prevention and Protection Division	Coordinate with safety office; inventory flammable/toxic materials; SARA Title III compliance.
Chief, DOL Transportation Branch	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
Chief, DOL Maintenance Division	Inventory control of materials and wastes; aviation maintenance wastes minimization.
Chief, DOL Supply and Services Division	Flag and control procurement of hazardous materials; coordinate with Safety and DES; establish chemical usage inventory and demand history by each generator.
Chief, MEDDAC Logistics	Flag and control procurement of hazardous materials; coordinate with Safety and DES; establish chemical usage inventory and demand history by each laboratory and generator.
Education Services Officer, DPCA Education Center	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
Chief, DPTM Training Division	Inventory control of materials and wastes; photographic and printing wastes minimization.
Chief, Preventive Medicine, Irwin Army Community Hospital	Establish inventory of hazardous materials/wastes; establish waste generators monitoring program; coordinate minimization and proper disposal practices (infectious, hazardous, and radioactive wastes) with environmental office.

XO, 1st Brigade	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
XO, 2nd Brigade	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
XO, 4th Aviation Brigade	Inventory control of materials and wastes; aviation and vehicle maintenance wastes minimization.
XO, DIVARTY	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
XO, DISCOM	Inventory control of materials and wastes; vehicle maintenance, and industrial maintenance wastes minimization.
CDR, 101st SPT BN	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
CDR, 201st SPT BN	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
CDR, 701st SPT BN	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
XO, 937th Engineer Group	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
BN CDR, 34th Engineer Battalion	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
XO, 541st Maintenance Battalion	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
CDR, 121st Signal Battalion	Inventory control of materials and wastes; vehicle maintenance wastes minimization.

CDR, 101st Military Intelligence Battalion	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
CDR, 2nd Battalion, 3rd Air Defense Artillery	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
CDR, 1st Engineer Battalion	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
XO, Headquarters Command	Inventory control of materials and wastes; vehicle maintenance wastes minimization.
Hazardous Waste Managers	As discussed in Section 10.4.

10.2 Responsibilities of all HAZMIN Committee Members (except Director, DES)

10.2.1 Identify and prioritize activities required to achieve the goals outlined in this plan.

10.2.2 Provide information on HAZMIN techniques to the actual generators of hazardous waste.

10.2.3 Organize a team to conduct annual HAZMIN assessments (or audits) to determine sources, types, and quantities of hazardous materials used and hazardous wastes generated.

10.2.4 Report on the status of the HAZMIN program to the Director, DES regularly.

10.2.5 Assist the Director, DES, in preparing an Annual HAZMIN status report.

10.3 Responsibilities of the Director, DES

10.3.1 Oversee and provide resources (including technological assistance) for conducting the annual HAZMIN assessments. Report the state of the HAZMIN program to the commander.

10.3.2 Revise and update this plan annually.

10.3.3 Prepare a HAZMIN status report when requested by HQFORSCOM or HQDA.

10.3.4 Program funds necessary to accomplish HAZMIN goals.

10.3.5 Chair the Hazardous Waste/Hazardous Materials working group.

10.3.6 Conceive, develop, and implement HAZMIN techniques consistent with this plan.

10.4 Responsibilities of Environmental (or Hazardous Waste) Managers

10.4.1 Establish goals for minimizing all forms of environmental pollution (air, water, solid, and hazardous waste).

10.4.2 Obtain training (organized by DES) on all the applicable environmental laws and train all subordinate personnel.

10.4.3 Implement better operating practices through inventory control (maintaining logbooks for materials procured and pollution generated); segregation of wastes; spill and leak prevention; and scheduling frequent preventive maintenance of equipment.

10.4.4 Examine and implement the use of substitute nonhazardous or less hazardous materials in place of hazardous materials.

10.4.5 Examine and implement process changes such as process modifications, equipment modifications, and changes in operation settings, to reduce the quantities of pollution generated.

10.4.6 Examine and implement technologies for recycling, reuse, or treatment of wastes. Information about technologies and equipment suppliers can be obtained from environmental personnel at DES.

Table A1. Summary of waste generated at Fort Riley.

DESCRIPTION	1989 LBS	1989 GALS	1990 LBS	1990 GALS	1991 LBS	1991 GALS
Safety Kleen Solvent Contract		N/A*		N/A		37,074
Solvents Disposed Through DRMO	12	421	23	2,350	195	567
Lead-Acid Battery Casings	N/A		N/A		300,000	
Lead-Acid Battery Electrolyte		4,607		3,580	23,878	271
Other Hazardous Batteries	19,449		5,193		10,615	
Paint Wastes		516	3,856	1,934	18,750	4,887
Used Motor Oil**		N/A		182,248		95,340
Other Petroleum, Oils, and Lubricants	62	4,245		7,000	97	739
Waste Antifreeze		1,685		1,447	29,487	
Acute Hazardous Wastes	25	30	2	8	21	4
Corrosive Acids and Bases	2,521	912	1,048	1,452	1,836	1,367
Toxic Hazardous Wastes	2,337	79	2,863	174	4,282	87
Ignitable Hazardous Wastes	27	3,063	1,308	5,214	3,509	1,930
Hazardous Pesticide Wastes	131	102	130	18	407	58
Hazardous Photography Wastes		3		65		10
Other Hazardous Wastes	19,080		8,353		592	
Other Controlled Wastes	2,949	881	5,885	5,733	5,753	3,664

* N/A indicates information on this waste was not available for this period. Blanks indicate no waste disposal for that period.

** Used motor oil is reported for fiscal years 1990 and 1991. All other quantities are reported for calendar years.

Appendix B: HAZMIN Assessment Protocol

Goals

1. Define current status of waste generation and management practices.
2. Identify and evaluate new waste minimization alternatives.
3. Identify support for existing alternatives/activities.
4. Identify areas/activities requiring further research and development.

Approach

I. Review information available at the installation.

II. Talk to several groups of individuals.

III. Develop a list of waste streams and rank them.

IV. Develop information on <u>each waste stream</u>.

V. Identify minimization options for <u>each waste stream</u>.

VI. Evaluate and rate options (preliminary or first screen) for <u>each waste stream</u>.

VII. Conduct detailed technical and economic feasibility analysis of select minimization options for high priority waste streams.

HAZMIN Protocol

I. Review information available at the installation.

The information reviewed by the survey team includes:

1. Installation policies/programs on waste minimization, if any.
2. Hazardous waste manifests, annual (and biennial) reports, and other Resource Conservation and Recovery Act information for all years available since 1985.
3. State and local regulations that are more stringent than Federal regulations.
4. Environmental audit/review reports.
5. Emission inventories.
6. Permit and/or permit applications, and any regulatory violations.
7. Contracts with waste management firms.
8. Waste assays and/or tests.
9. Maps, organizational charts, list of activities associated with different buildings.
10. Production/maintenance schedules.
11. Operator data logs, batch sheets.
12. Operation manuals, process descriptions, standing operating procedures (SOPs).
13. Process flow diagrams and facilities layout.
14. Safety procedures for handling hazardous materials.

Products:

1. List of information sources.

2. Waste stream list.

3. Survey agenda or checklist detailing what is to be accomplished.

4. List of questions that need to be resolved.

5. List of information that needs to be gathered.

HAZMIN Protocol

II. Talk to several groups of individuals.

1. Environmental personnel
   - who compile U.S. Environmental Protection Agency (USEPA)/ State reports
   - who compile Defense Reutilization and Marketing Office (DRMO) reports

2. Waste generators
   - supervisors
   - shop foremen and production employees

3. Hazardous waste managers
   - operators of on-site treatment, storage, and disposal (TSD) facilities
   - transporters of waste from generation points to TSD facilities

4. Individuals responsible for purchasing/acquisition of hazardous materials (for possible substitution alternatives, costs of purchase, etc.)

5. Individuals with broad HAZMIN responsibilities
   - finance and accounting
   - construction/renovation of facilities
   - higher levels of management
   - legal advisors

HAZMIN Protocol

III. Develop a list of waste streams and rank them.

Develop a waste generation inventory based on DRMO delivery orders, disposal contracts, disposal logbooks, and permits. Inventory should be representative of "normal" operations.

Ranking criteria:

1. Composition
2. Quantity (volume or mass generated per year and unit of production)
3. Degree of hazard (toxicity, flammability, corrosivity, etc.)
4. Method and cost of disposal
5. Potential for minimization and recycling
6. Compliance status (in or out)
7. Potential liability (past spills or accidents; proximity to water)
8. Degree of acceptability of changes at the installation
9. Installation personnel preference for options

Products:

1. Waste description with rationale for selection
2. Description of facilities, processes, and waste streams

HAZMIN Protocol

IV. Develop information on each waste stream.

The following information must be developed on each waste stream based on observation and available reports:

1. Waste characterization
   - chemical/physical analysis
   - reason for hazardous nature

2. Waste source

3. Baseline generation

4. Present method of TSD and associated costs

5. Past/present minimization efforts and associated costs

Some points to be reviewed in the above determination are:

- actual point of generation
- details about subsequent handling/mixing
- hazardous versus nonhazardous
- physical and chemical characteristics
- quantities by waste treatability category
- potential variations in the rate of production, maintenance, etc.
- potential for contamination or upset
- true costs for management, onsite and offsite including tax, fringe, and overhead for labor; cost of space; vehicle insurance, maintenance, fuel, etc.

HAZMIN Protocol

V. Identify minimization options for each waste stream.

Follow USEPA guidelines on waste minimization. The categories arranged in a hierarchical order are:

1. Source reduction
   a. product/material substitution
   b. source control
      i. input material changes (e.g., dilution, purification)
      ii. technology changes (e.g., process changes, layout changes, etc.)
      iii. procedural/institutional changes

2. Recycle/reuse
   a. onsite
   b. offsite

3. Waste separation and concentration

4. Waste exchange

5. Energy/material recovery

6. Waste incineration/treatment

7. Treatment

8. Ultimate disposal

HAZMIN Protocol

VI. Evaluate and rate options (preliminary or first screen) for each waste stream.

Some considerations for a preliminary evaluation and rating of minimization options for each waste stream are:

1. Waste reduction effectiveness (i.e., reduction of waste quantity and/or toxicity)
2. Extent of current use in the facility
3. Industrial precedent
4. Technical soundness
5. Cost (preliminary capital and operating cost evaluation)
6. Effect on product quality
7. Effect on operations
8. Implementation period
9. Resources availability and requirement

HAZMIN Protocol

VII. Detailed technical and economic feasibility analysis of select minimization options for high priority waste streams.

The following aspects must be considered in the final detailed analysis:

1. Technical soundness and commercial availability

2. Evaluation of detailed life cycle costs of all the options for each waste stream

3. Detailed comparison of costs of the current practices with alternative options to obtain savings to investment ratios and discounted payback periods

4. Implementation period

List of Abbreviations and Acronyms

AFFF	Aqueous Film Forming Foam
AMF	Aviation Maintenance Facility
AR	Army Regulation
ASTM	American Society of Testing and Materials
Btu	British thermal unit
CARC	Chemical Agent Resistant Coating
CDR	Commander
CFR	Code of Federal Regulations
CLIN	Contract Line Item Number
CW	Chemotherapy Wastes
CY	Calendar Year
DA	Department of the Army
DDS	Director of Dental Services
DERA	Defense Environmental Restoration Account
DES	Directorate of Environment and Safety
DHS	Director of Health Services
DLA	Defense Logistics Agency
DOD	Department of Defense
DODAAC	Department of Defense Activity Address Code
DOL	Directorate of Logistics
DOT	Department of Transportation
DPCA	Directorate of Personnel and Community Activities
DPP	Discounted Payback Period

DPTM	Directorate of Plans, Training, and Mobilization
DRMO	Defense Reutilization and Marketing Office
DRMS	Defense Reutilization and Marketing Service
EP	Extraction Procedure
ETIS	Environmental Technical Information System
FORSCOM	U.S. Army Forces Command
FY	Fiscal Year
GW	General Wastes
HAZMIN	Hazardous Waste Minimization
HCL	Hospitals, Clinics, and Laboratories
HM	Hazardous Materials
HMIS	Hazardous Material Information Sheet
HQ	Headquarters
HSWA	Hazardous and Solid Waste Amendments
HVLP	High Volume-Low Pressure Painting
HW	Hazardous Waste
HWMB	Hazardous Waste Management Board
HWPS	Hazardous Waste Profile Sheet
IG	Inspector General
IL	Infectious Linen
IMSS	Industrial Maintenance, Small Arms Shops
IW	Infectious Wastes
JLC	Joint Logistics Commanders
LPI	Leak Potential Index
LW	Laboratory Wastes
MC	Methylene Chloride
MEDDAC	Medical Department Activity
MPRSA	Marine Protection, Research and Sanctuaries Act

MPVM	Motor Pools and Vehicle Maintenance Facilities
MSDS	Material Safety Data Sheet
MWSA	Medical Waste Sanctions Act
NICAD	Nickel Cadmium Battery
NIPER	National Institute for Petroleum and Energy Research
NPV	Net Present Value
OB/OD	Open Burning/Open Detonation
OEM	Original Equipment Manufacture
OSHA	Occupational Safety and Health Administration
PAO	Public Affairs Officer
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
PECI	Defense Productivity Enhancing Capitol Investment
PEP	Propellants, Explosives and Pyrotechnics
PERC	Perchloroethylene (Tetrachloroethylene)
PhW	Pharmaceutical Wastes
PMB	Plastic Media Blasting
POL	Petroleum, Oils, and Lubricants
PPAS	Photography, Printing, and Arts/Crafts Shops
PS	Paint Shops
PW	Pathological Wastes
RO	Reverse Osmosis
RW	Radioactive Wastes
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SIR	Savings to Investment Ratio
SK	Safety Kleen, Inc.
SOP	Standing Operating Procedure

SQG	Small Quantity Generator
TCE	Trichloroethylene
TM	Technical Manual
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage, and Disposal
USACERL	U.S. Army Construction Engineering Research Laboratory
USAEHA	U.S. Army Environmental Hygiene Agency
USAISC	U.S. Army Information Systems Command
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USE	Used Solvent Elimination
USEPA	U.S. Environmental Protection Agency
UST	Underground Storage Tank
UV	Ultraviolet
XO	Executive Officer

USACERL DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECC-R
ATTN: CERD-L

US Army Materiel Command (AMC)
Alexandria, VA 22333-0001
ATTN: AMCEN-F
Installations: (19)

FORSCOM
Forts Gillem & McPherson 30330
ATTN: FCEN
Installations: (23)

TRADOC
Fort Monroe 23651
ATTN: ATBO-G
Installations: (20)

Commander, Fort Riley, KS
ATTN: AFZN-ES-P (10)

Commander, U.S. Army Environmental Hygiene Agency
ATTN: HSHB-ME-SH

Defense Tech Info Center 22304
ATTN: DTIC-FAB (2)

84
3/95